US010503944B2

(12) **United States Patent**
Lei et al.

(10) **Patent No.: US 10,503,944 B2**
(45) **Date of Patent: *Dec. 10, 2019**

(54) **BARCODE-READING SYSTEM THAT OBTAINS RANGING DATA VIA TARGETING ILLUMINATION**

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(72) Inventors: **Ming Lei**, Princeton Junction, NJ (US); **George Powell**, Draper, UT (US)

(73) Assignee: **THE CODE CORPORATION**, Draper, UT (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **16/259,942**

(22) Filed: **Jan. 28, 2019**

(65) **Prior Publication Data**

US 2019/0156087 A1 May 23, 2019

Related U.S. Application Data

(63) Continuation of application No. 15/936,044, filed on Mar. 26, 2018, which is a continuation of application

(Continued)

(51) **Int. Cl.**

G06K 19/08 (2006.01)
G06K 7/10 (2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ***G06K 7/10722*** (2013.01); ***G06F 16/9554*** (2019.01); ***G06K 7/10732*** (2013.01);

(Continued)

(58) **Field of Classification Search**

CPC G06K 7/12; G06K 7/14; G06K 7/10861

(Continued)

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(Continued)

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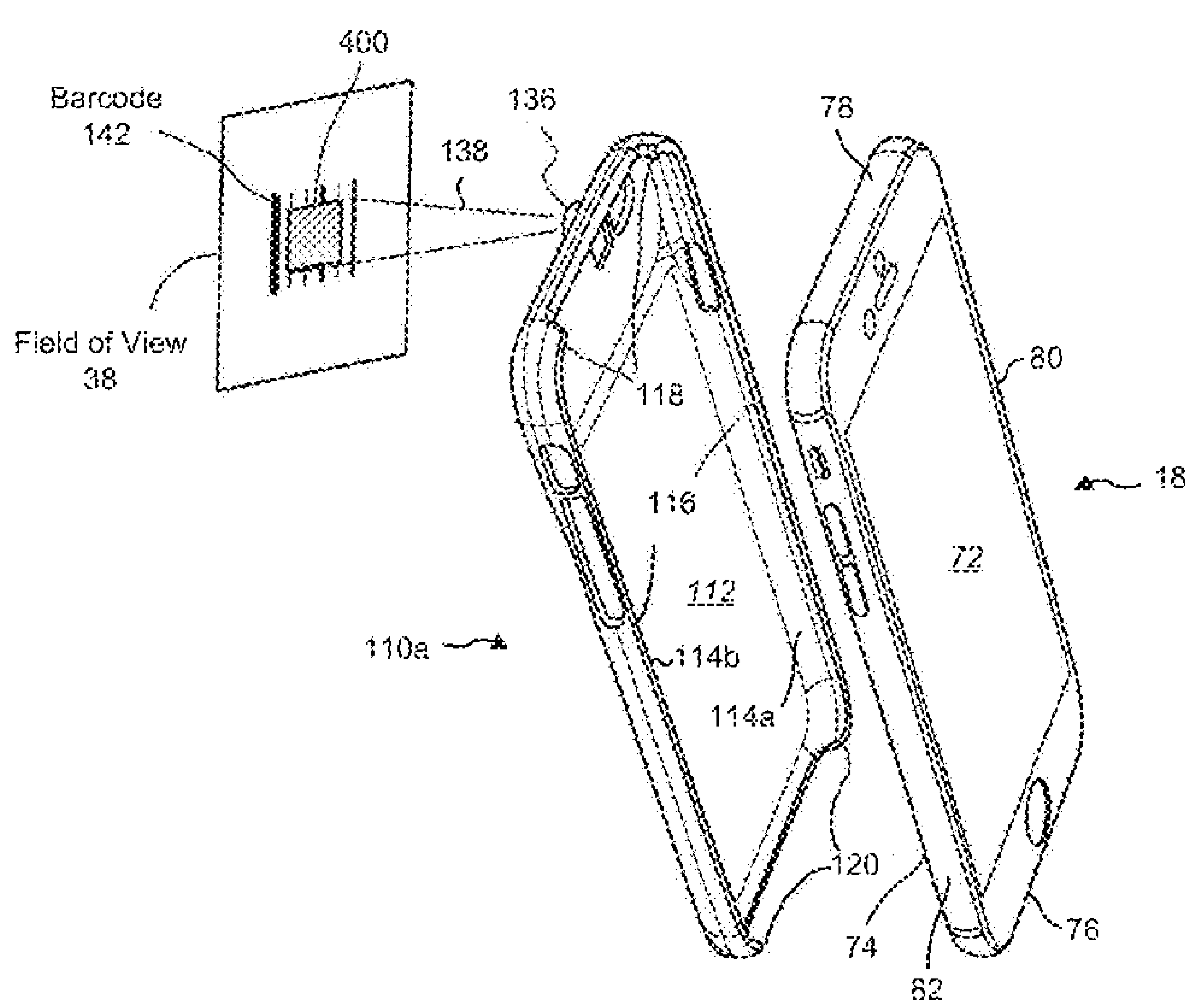
Primary Examiner — Daniel St Cyr

(74) *Attorney, Agent, or Firm* — Timothy P. O'Hagan; Ray Quinney & Nebeker

(57) **ABSTRACT**

A barcode-reading system may include a barcode-reading enhancement accessory that is securable to a mobile device. The accessory may include an optic system that is configured to shape and filter illumination from a white light source of the mobile device to project targeting illumination onto a target surface. Calibration data may indicate a relationship between surface distance and at least one feature offset of the targeting illumination. A barcode-reading application may determine a feature offset of the targeting illumination in an image that is captured by the camera assembly of the mobile device. The application may also determine an estimated surface distance based on the calibration data and the feature offset. The application may also use the estimated surface distance to adjust at least one operating parameter of the mobile device.

20 Claims, 64 Drawing Sheets



Related U.S. Application Data

No. 15/621,239, filed on Jun. 13, 2017, now Pat. No. 9,928,392, which is a continuation-in-part of application No. 15/207,484, filed on Jul. 11, 2016, now Pat. No. 9,665,760, which is a continuation-in-part of application No. 14/304,830, filed on Jun. 13, 2014, now Pat. No. 9,679,175.

(60) Provisional application No. 62/318,216, filed on Apr. 5, 2016.

(51) **Int. Cl.**

G06K 19/06	(2006.01)
G06K 7/14	(2006.01)
G06F 16/955	(2019.01)
H04W 88/02	(2009.01)

(52) **U.S. Cl.**
CPC ***G06K 7/10831*** (2013.01); ***G06K 7/10881*** (2013.01); ***G06K 7/1413*** (2013.01); ***G06K 7/1417*** (2013.01); ***G06K 7/1447*** (2013.01); ***G06K 7/1478*** (2013.01); ***G06K 19/06028*** (2013.01); *H04W 88/02* (2013.01)

(58) **Field of Classification Search**
USPC 235/455, 462.04, 462.06
See application file for complete search history.

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2017/0004340	A1	1/2017	Powell	

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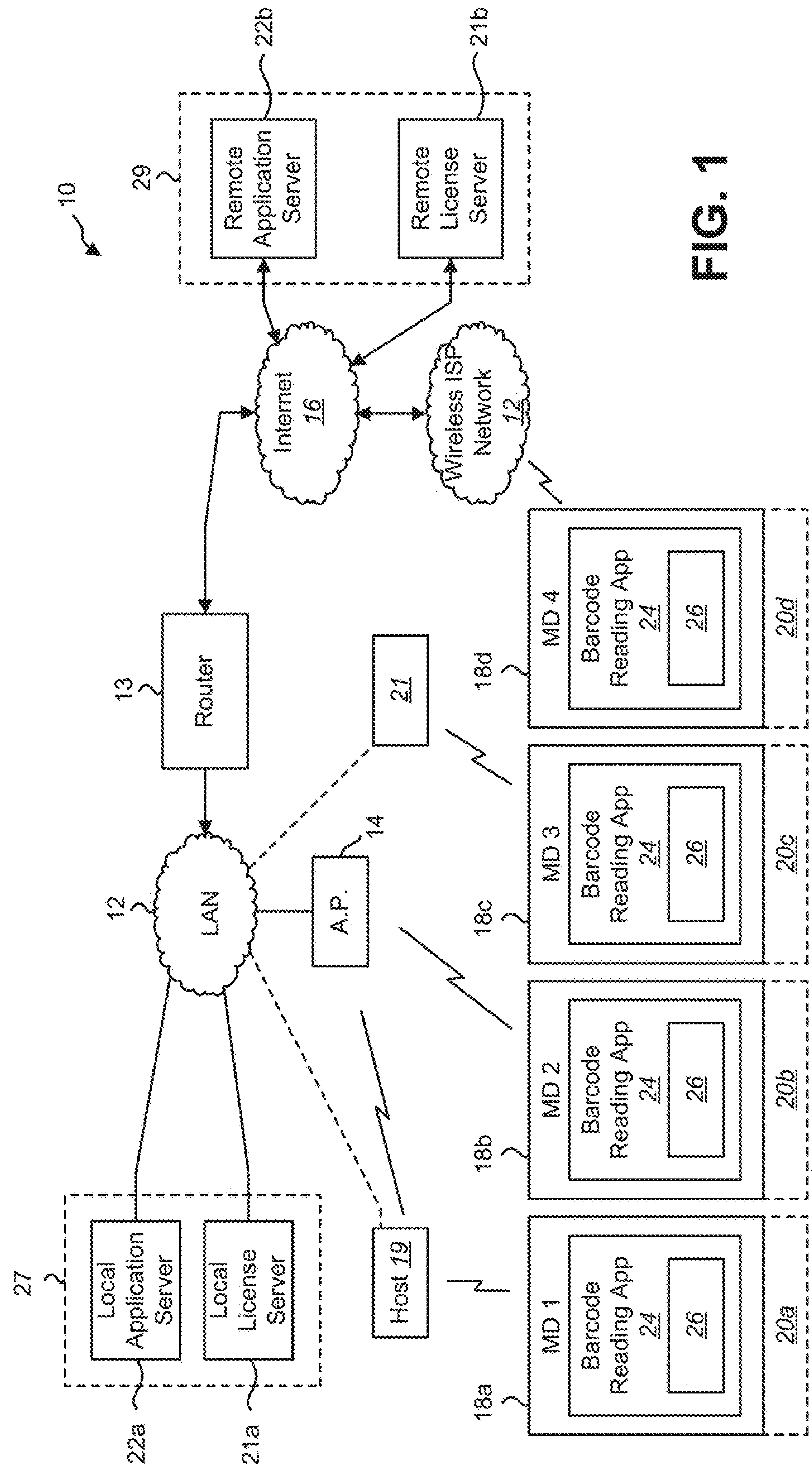

10
29
Remote Application Server
22b
Remote License Server
21b
Internet 16
Wireless ISP Network 12
Router
13
LAN
12
A.P.
14
21
Host 19
27
Local Application Server
22a
Local License Server
21a
MD 1
MD 2
MD 3
MD 4
Barcode Reading App 24
26
18a
18b
18c
18d
20a
20b
20c
20d

FIG. 1

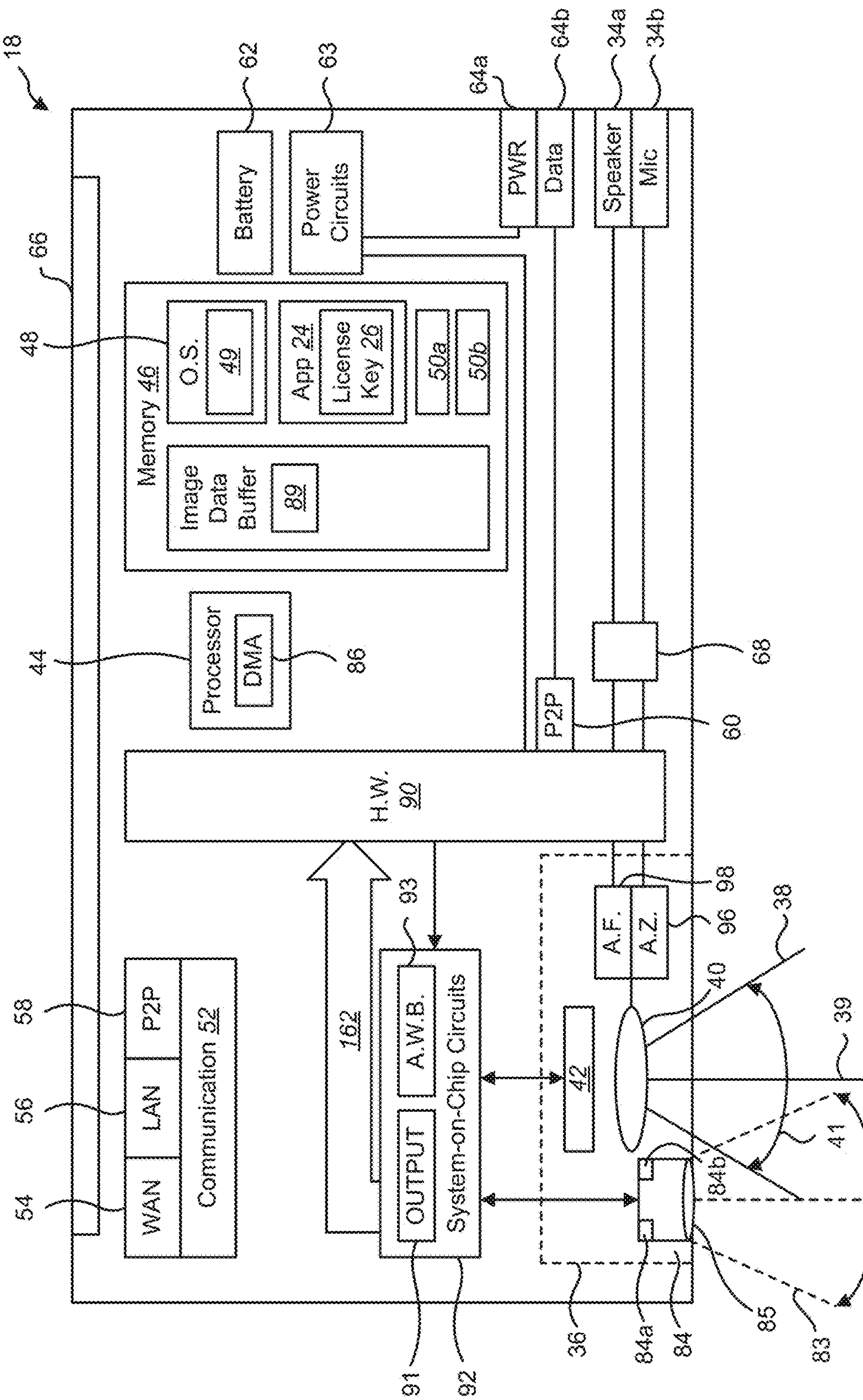
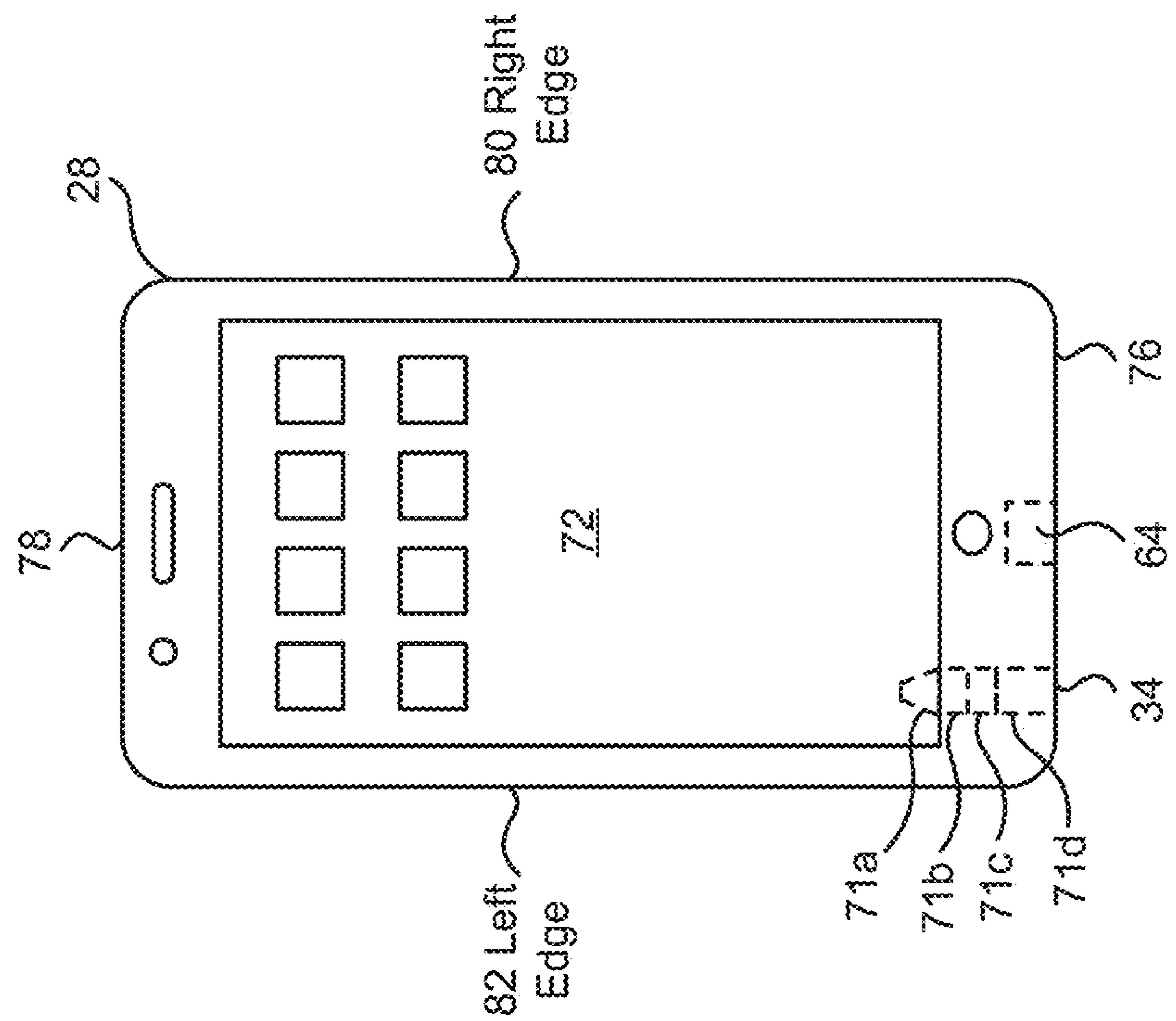
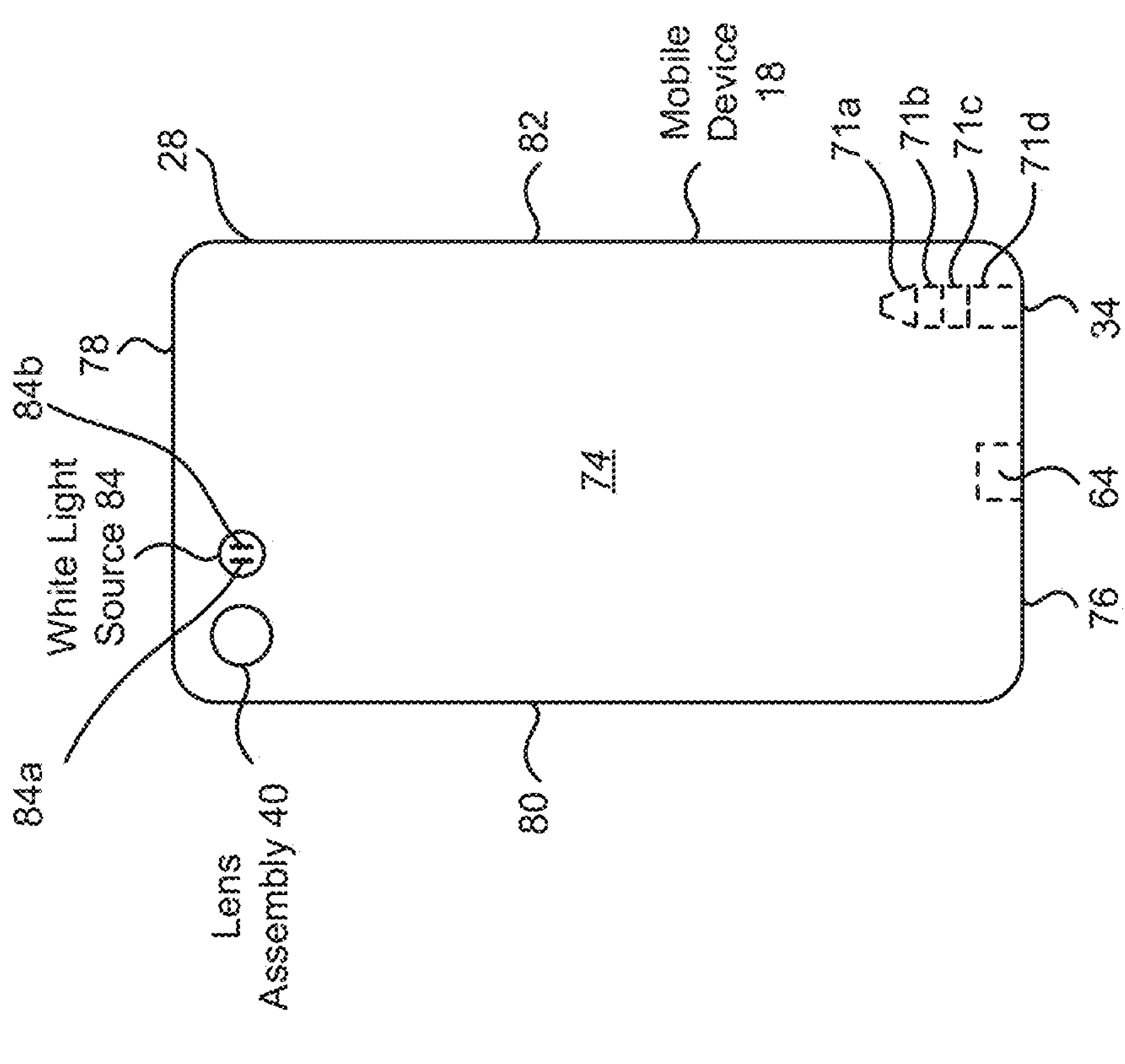

18
66
62
63
64a
64b
34a
34b
Battery
Power Circuits
PWR
Data
Speaker
Mic
48
Memory 46
O.S.
49
App 24
License Key 26
50a
50b
Image Data Buffer
89
44
Processor
DMA
86
68
P2P
60
H.W.
90
162
93
98
96
38
A.F.
A.Z.
40
39
42
41
87
89
84b
58
56
54
P2P
LAN
WAN
Communication 52
OUTPUT
A.W.B.
System-on-Chip Circuits
91
92
36
84a
84
85
83

FIG. 2A



28
80 Right Edge
78
72
76
64
34
82 Left Edge
71a
71b
71c
71d

FIG. 2C



84b
White Light Source 84
78
28
82
Mobile Device 18
71a
71b
71c
71d
74
34
64
76
84a
Lens Assembly 40
80

FIG. 2B

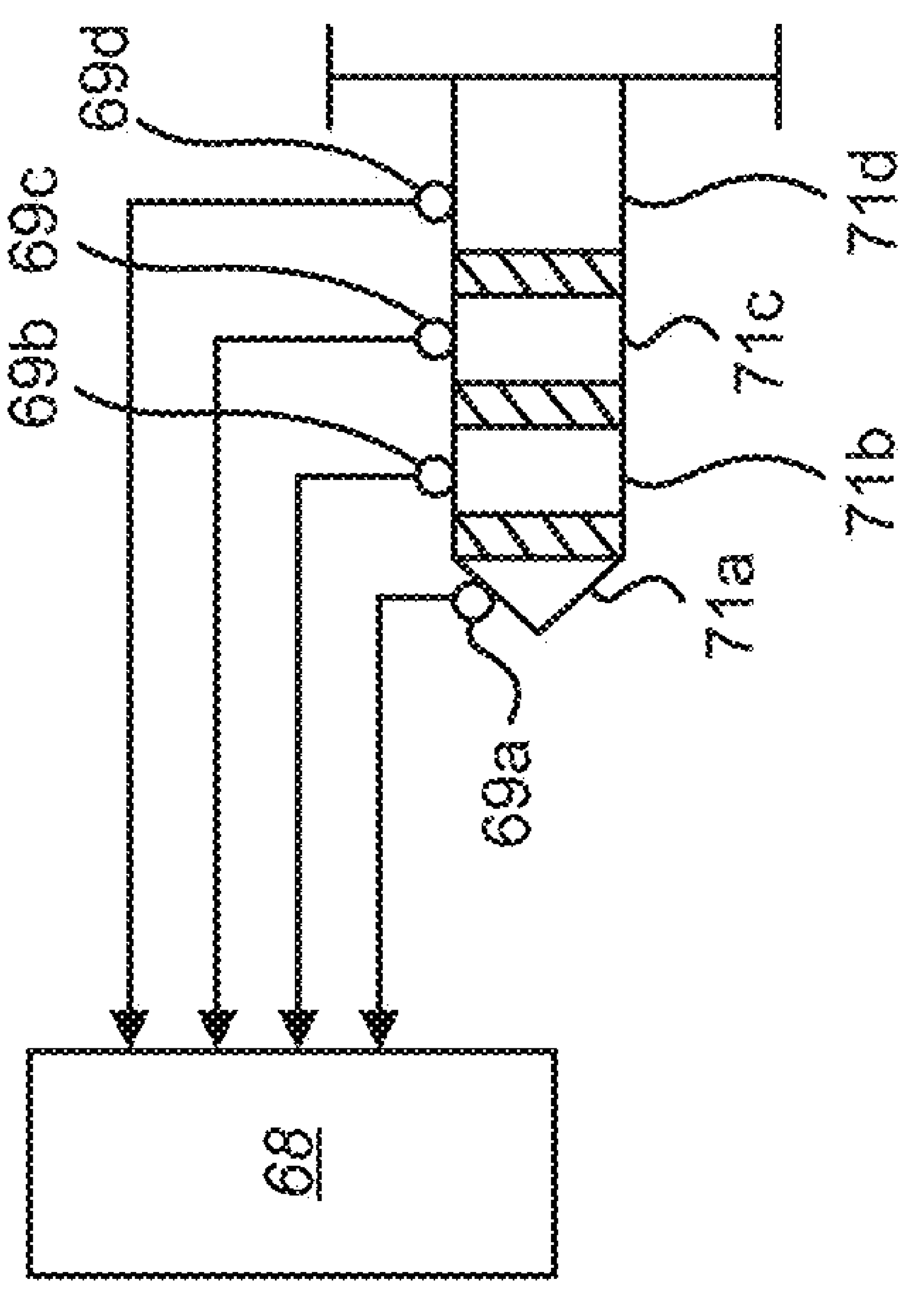

68
69a
69b
69c
69d
71a
71b
71c
71d

FIG. 2D

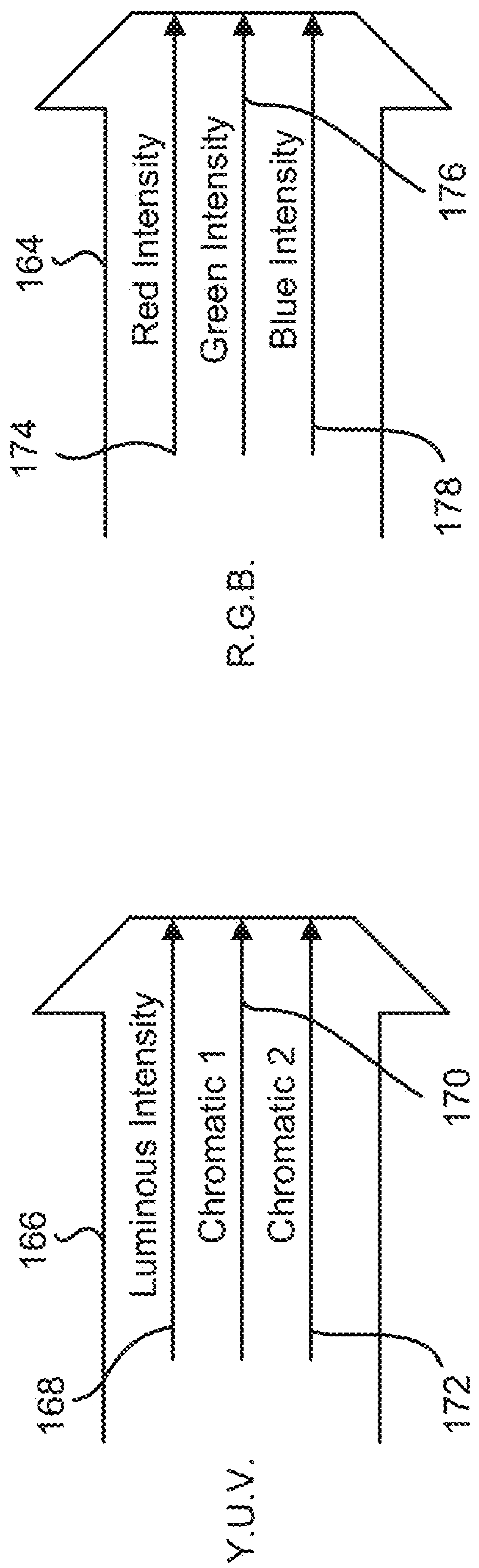

Y.U.V.
Luminous Intensity
Chromatic 1
Chromatic 2
166
168
170
172
R.G.B.
Red Intensity
Green Intensity
Blue Intensity
164
174
176
178

FIG. 2E

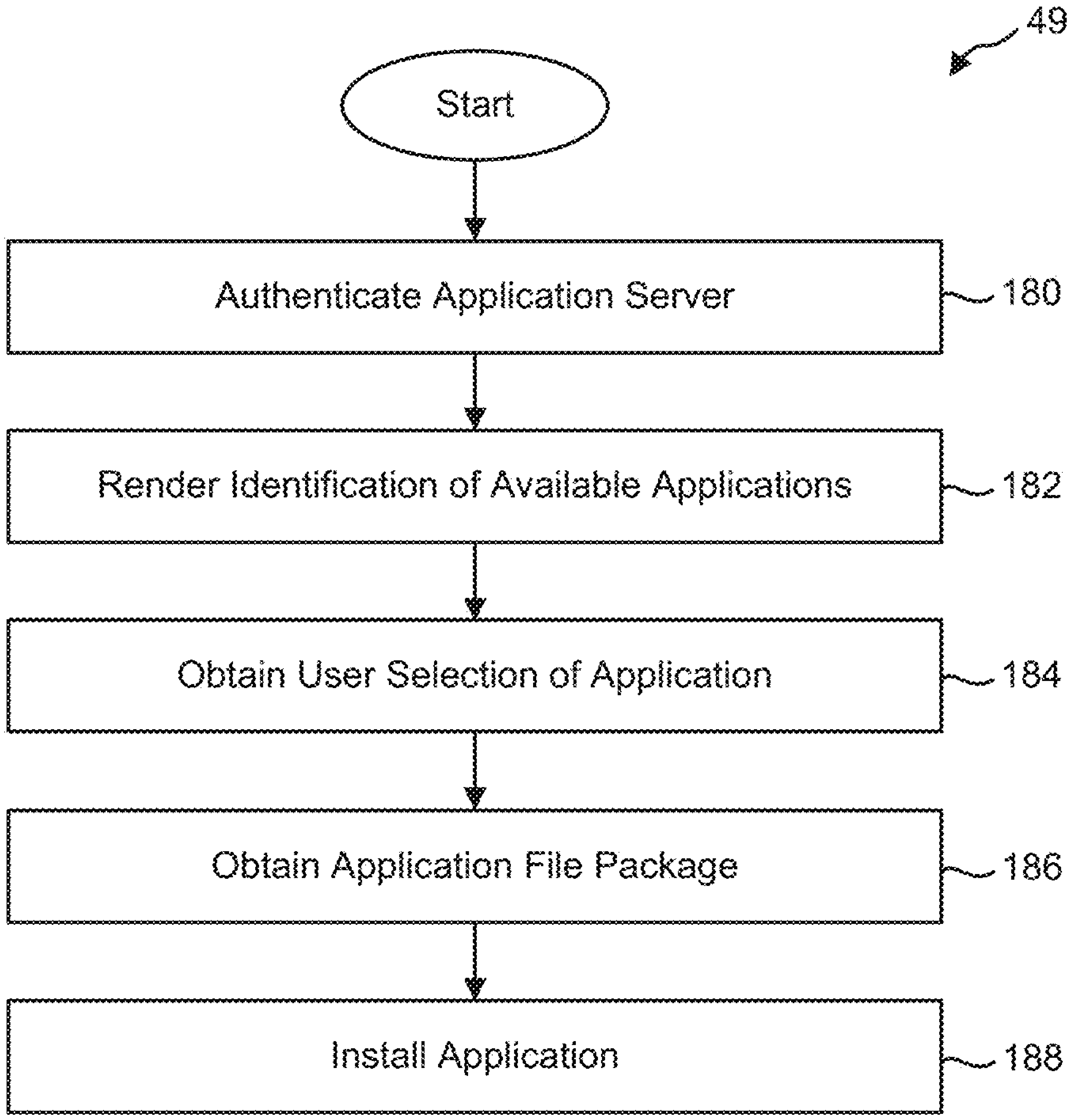

49
Start
Authenticate Application Server
180
Render Identification of Available Applications
182
Obtain User Selection of Application
184
Obtain Application File Package
186
Install Application
188

FIG. 3A

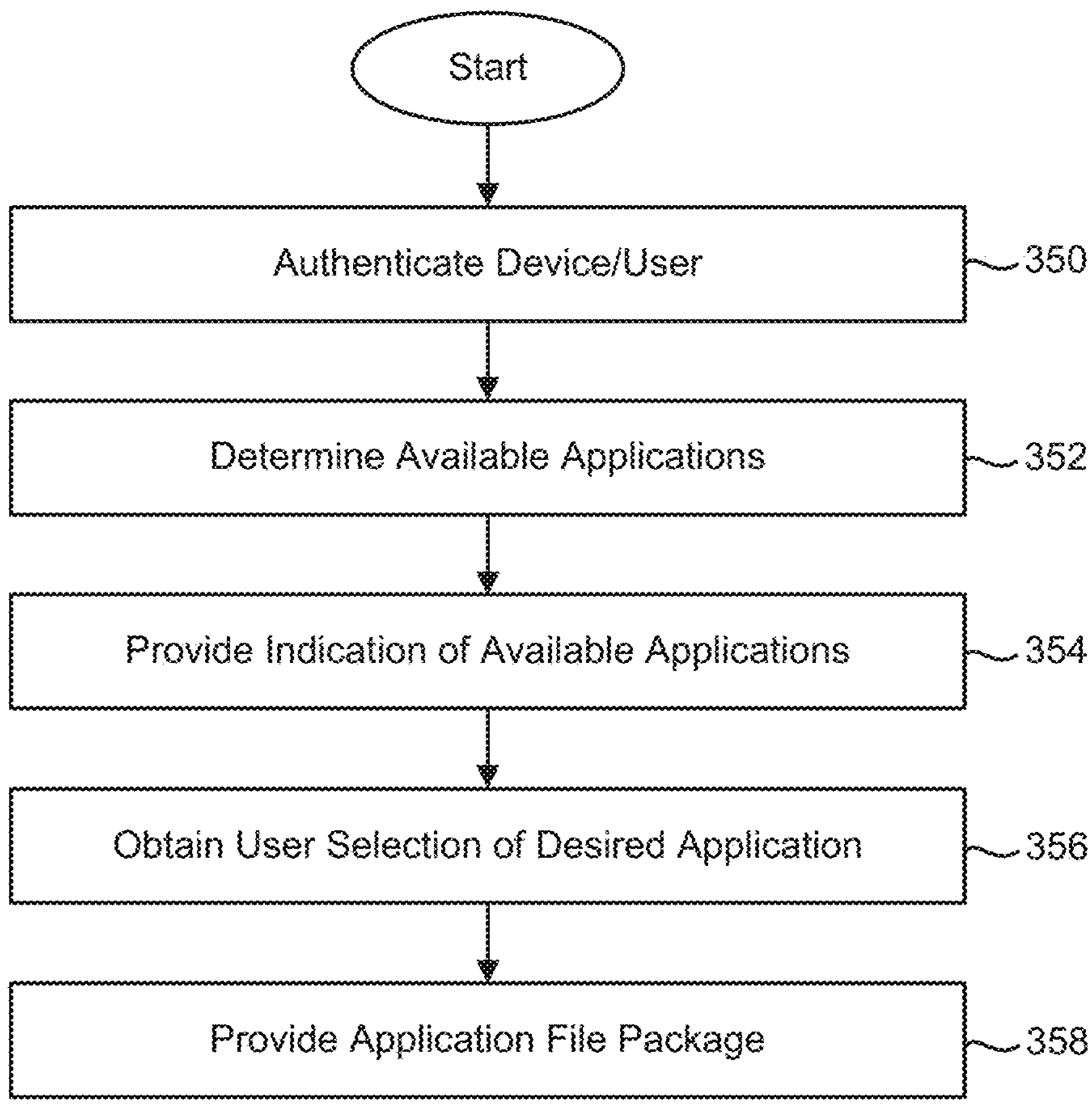

Start
Authenticate Device/User
350
Determine Available Applications
352
Provide Indication of Available Applications
354
Obtain User Selection of Desired Application
356
Provide Application File Package
358

FIG. 3B

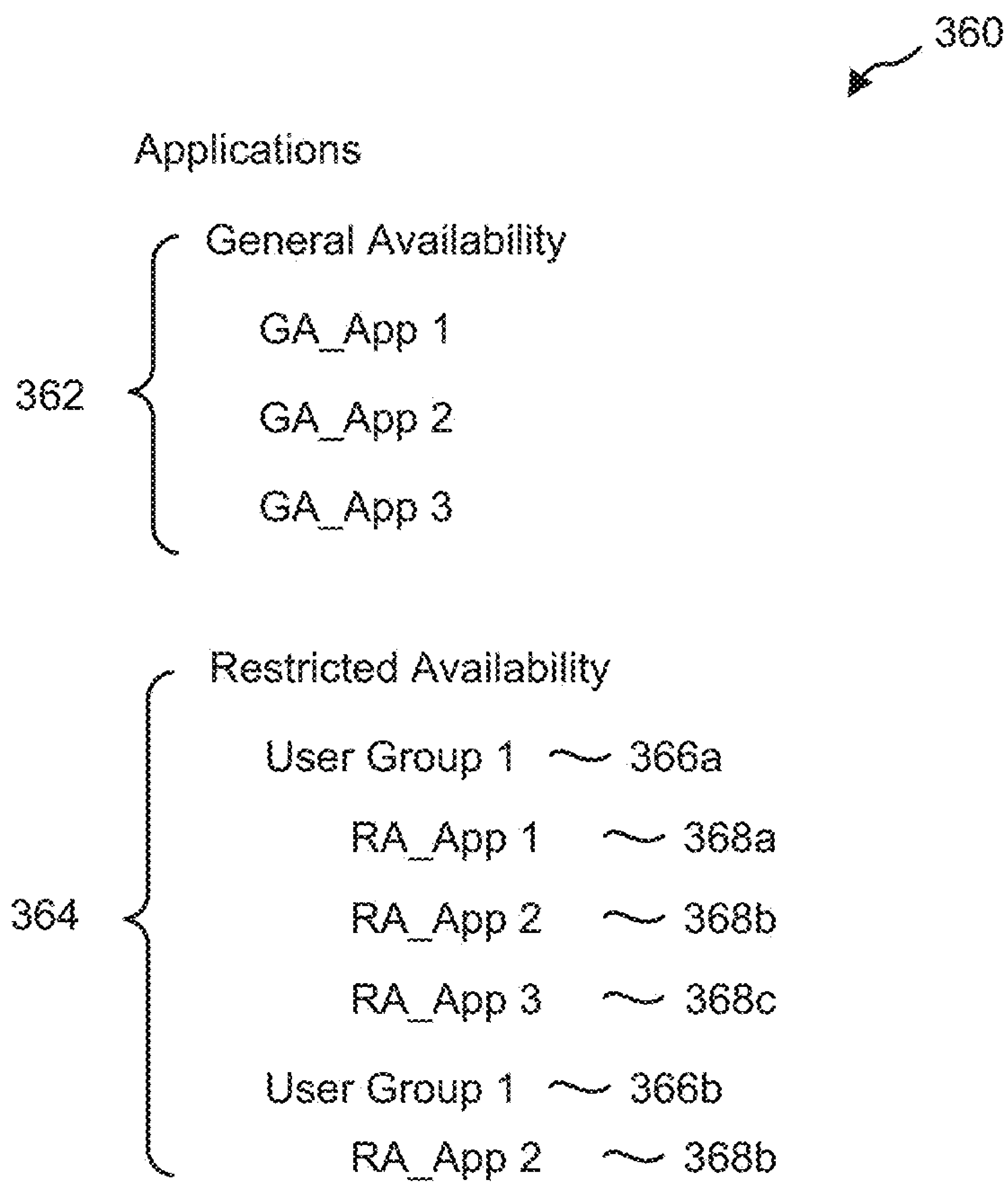

360
Applications
General Availability
GA_App 1
GA_App 2
GA_App 3
362
Restricted Availability
User Group 1 366a
RA_App 1 368a
RA_App 2 368b
RA_App 3 368c
User Group 1 366b
RA_App 2 368b
364

FIG. 3C

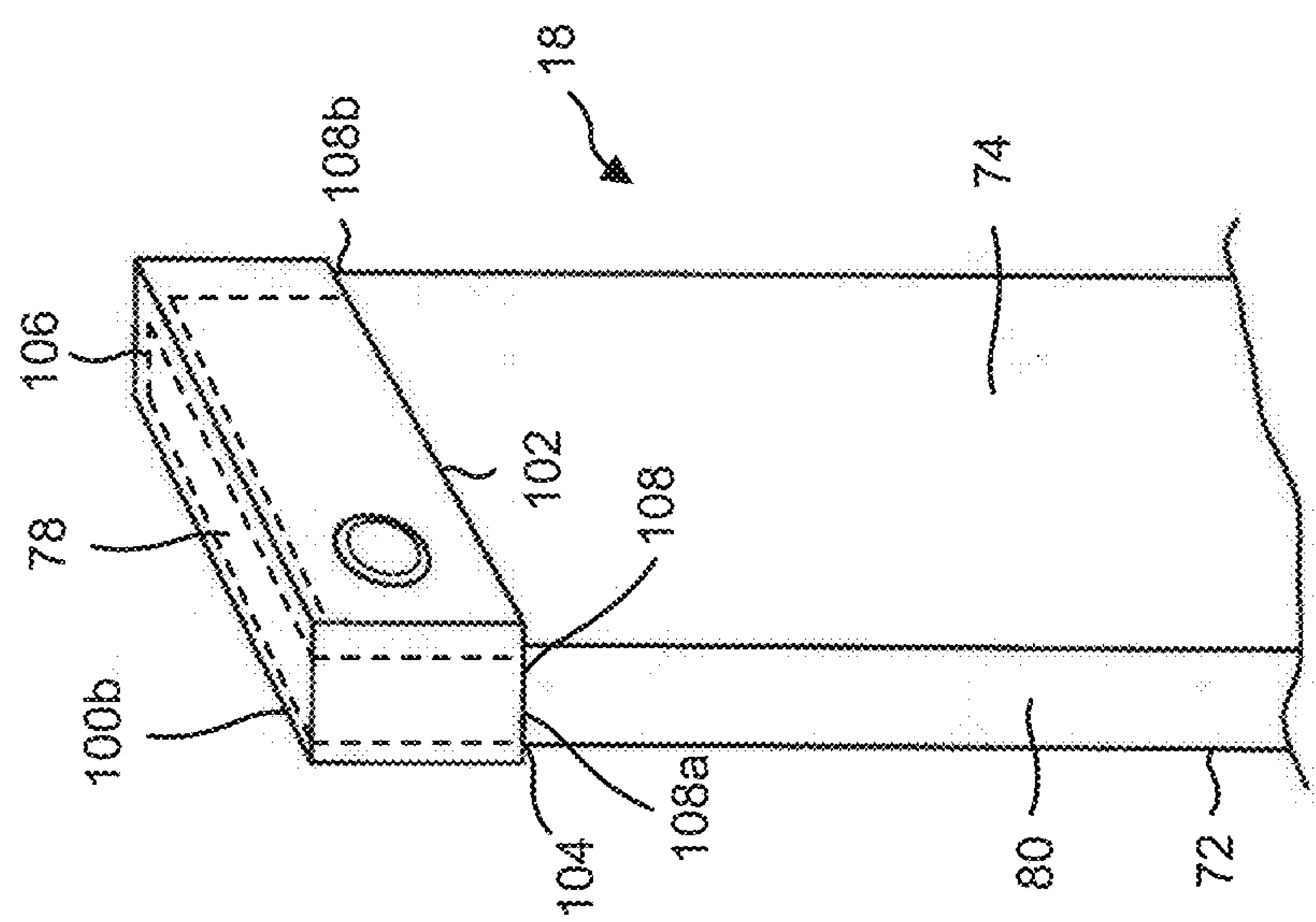

18
108b
74
106
102
78
108
100b
108a
104
80
72

FIG. 4B

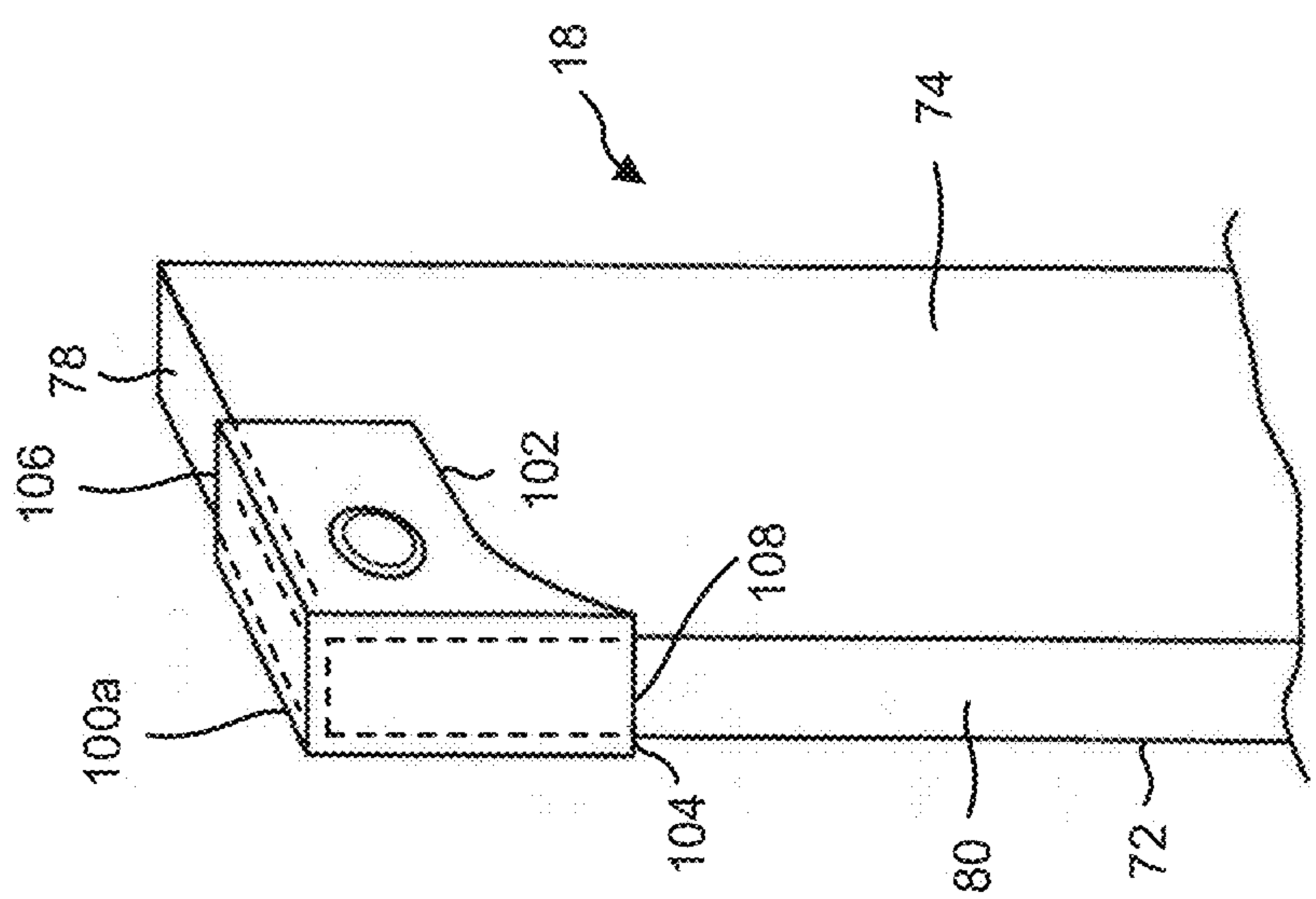

18
74
78
106
102
108
100a
104
80
72

FIG. 4A

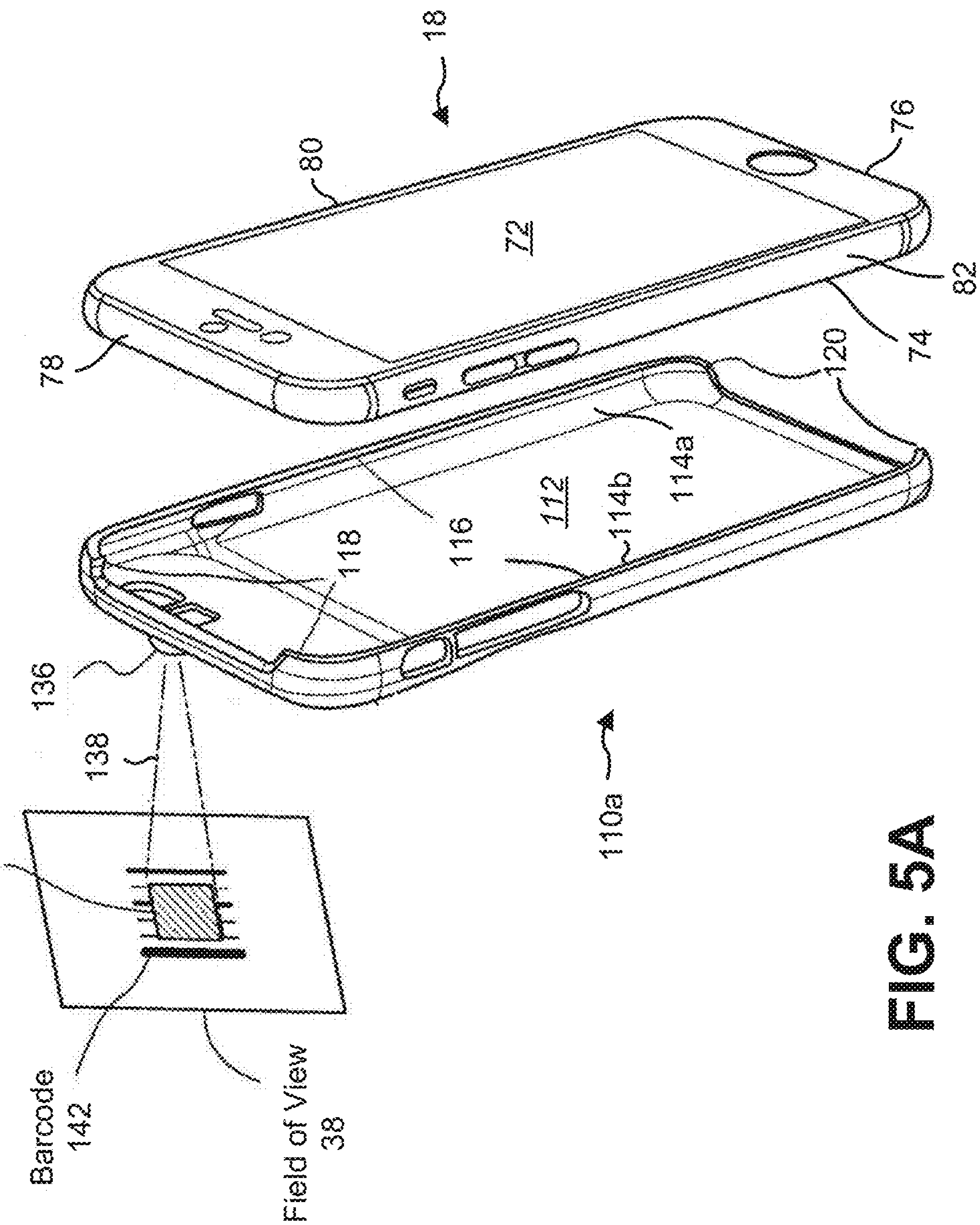

18
80
76
72
78
82
74
120
114a
112
114b
116
118
136
138
110a
400
Barcode
142
Field of View
38

FIG. 5A

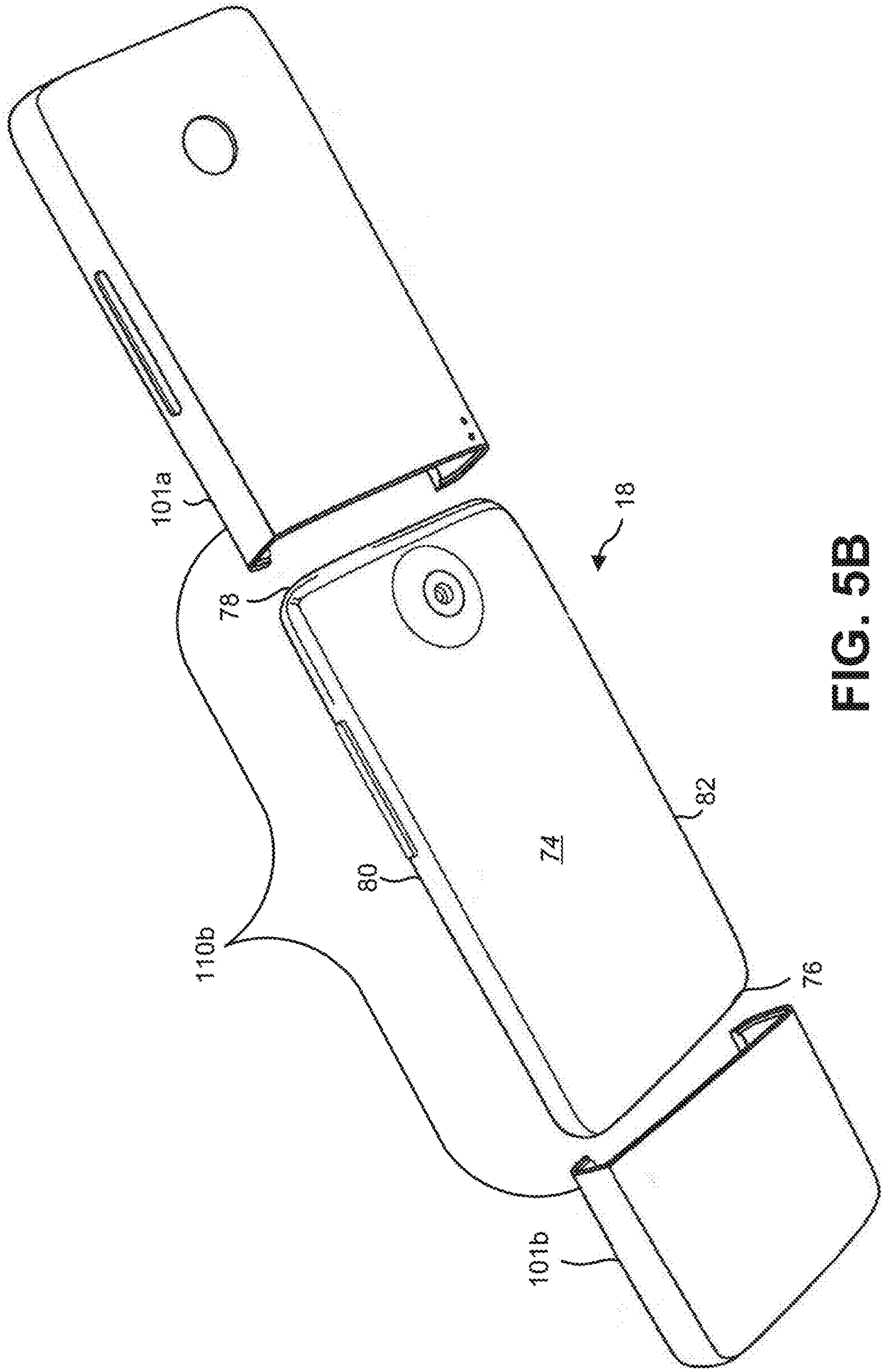


FIG. 5B

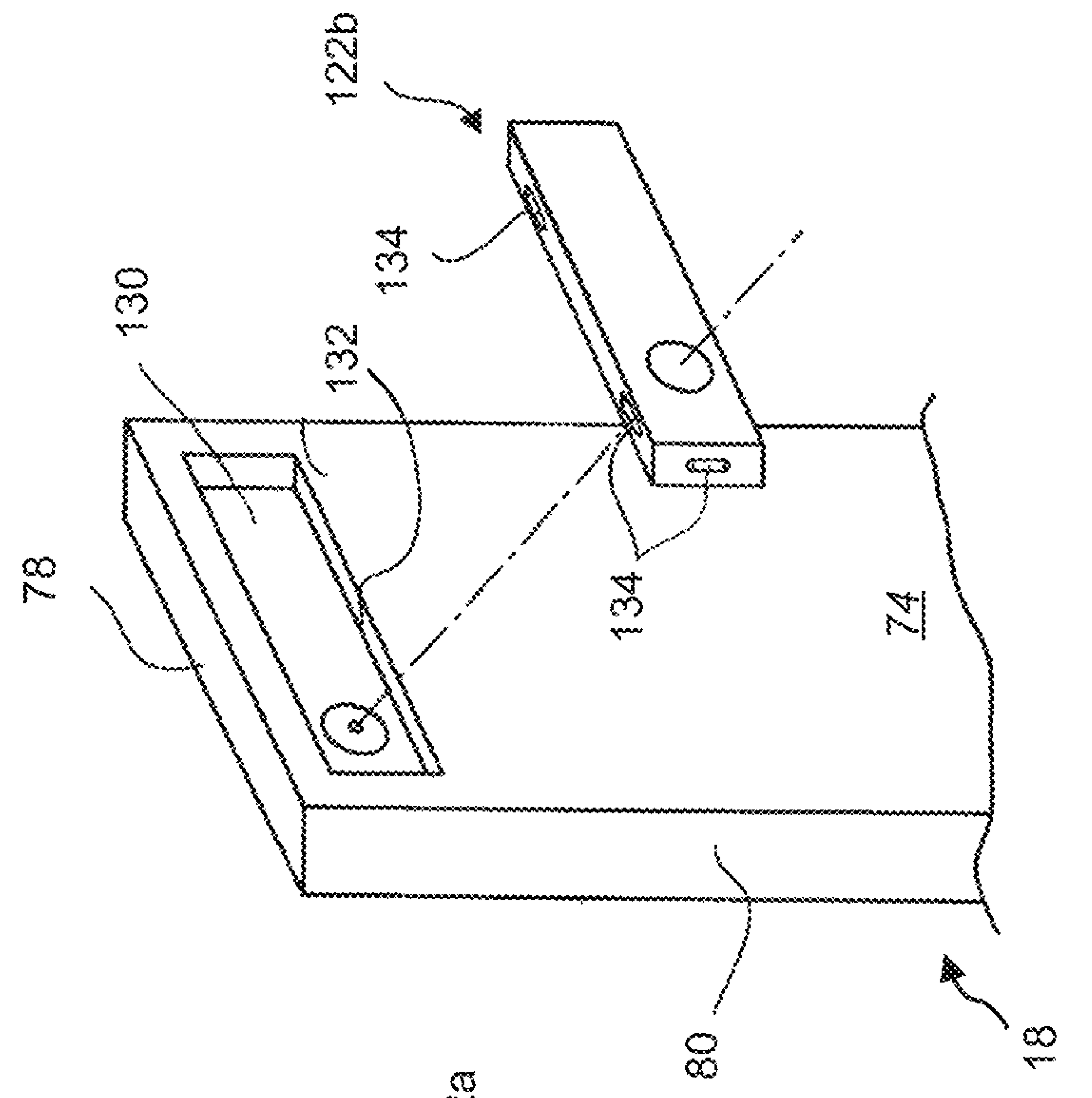


FIG. 6B

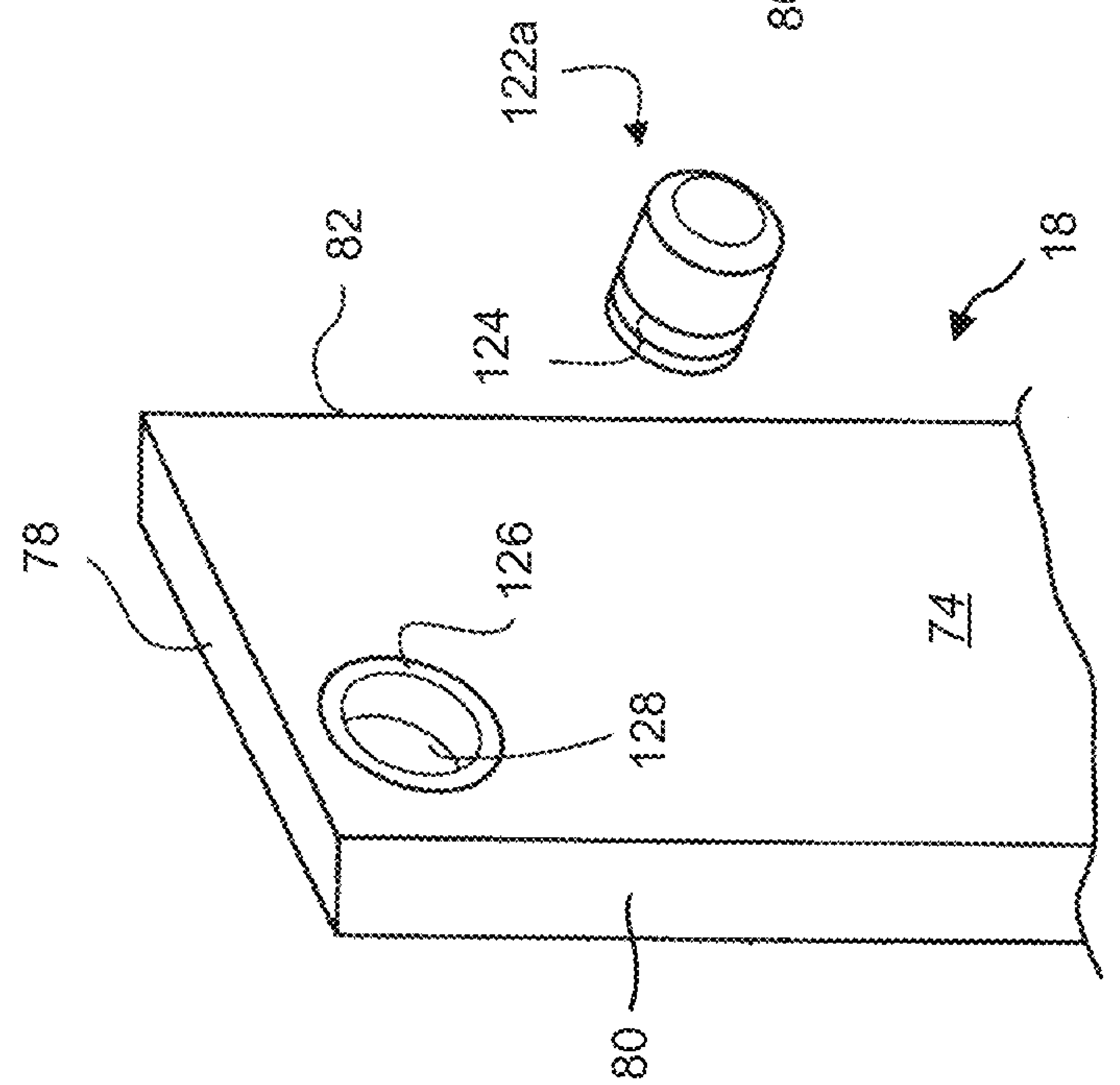


FIG. 6A

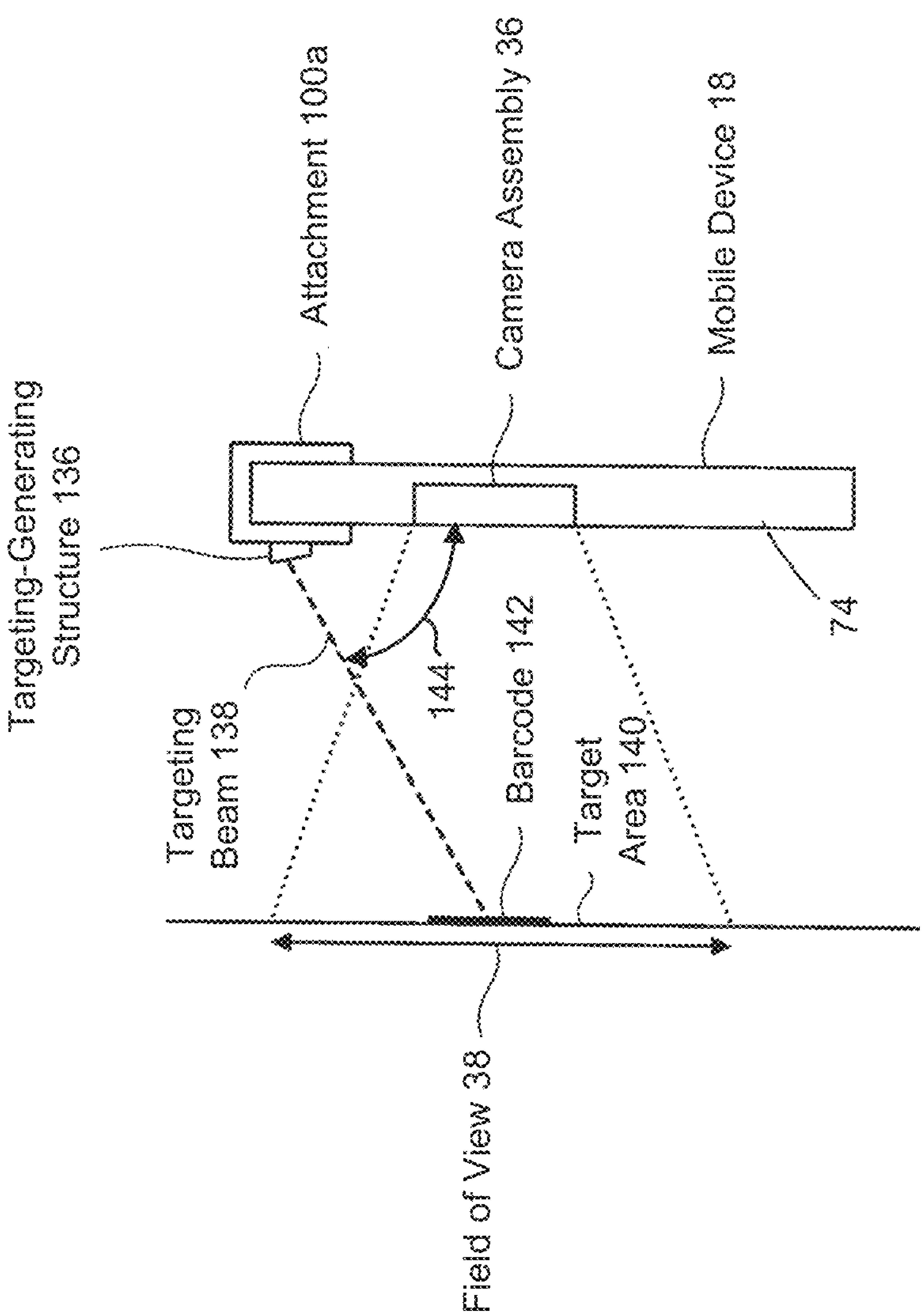

Attachment 100a
Camera Assembly 36
Mobile Device 18
Targeting-Generating Structure 136
Targeting Beam 138
144
74
Barcode 142
Target Area 140
Field of View 38

FIG. 7A

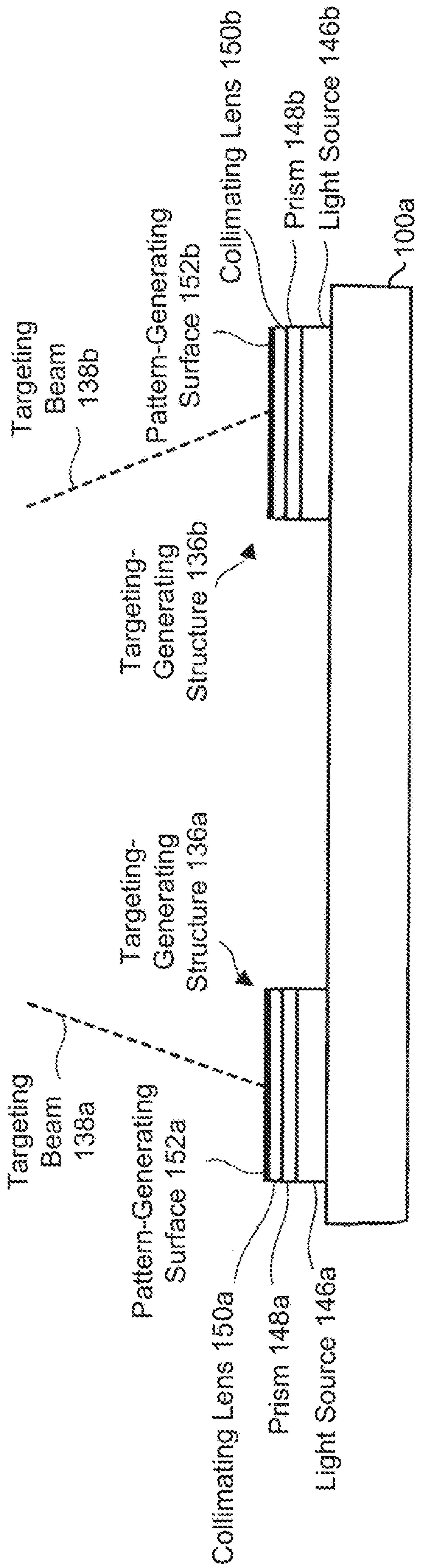

Collimating Lens 150b
Prism 148b
Light Source 146b
100a
Targeting Beam 138b
Pattern-Generating Surface 152b
Targeting-Generating Structure 136b
Targeting-Generating Structure 136a
Targeting Beam 138a
Pattern-Generating Surface 152a
Collimating Lens 150a
Prism 148a
Light Source 146a

FIG. 7B

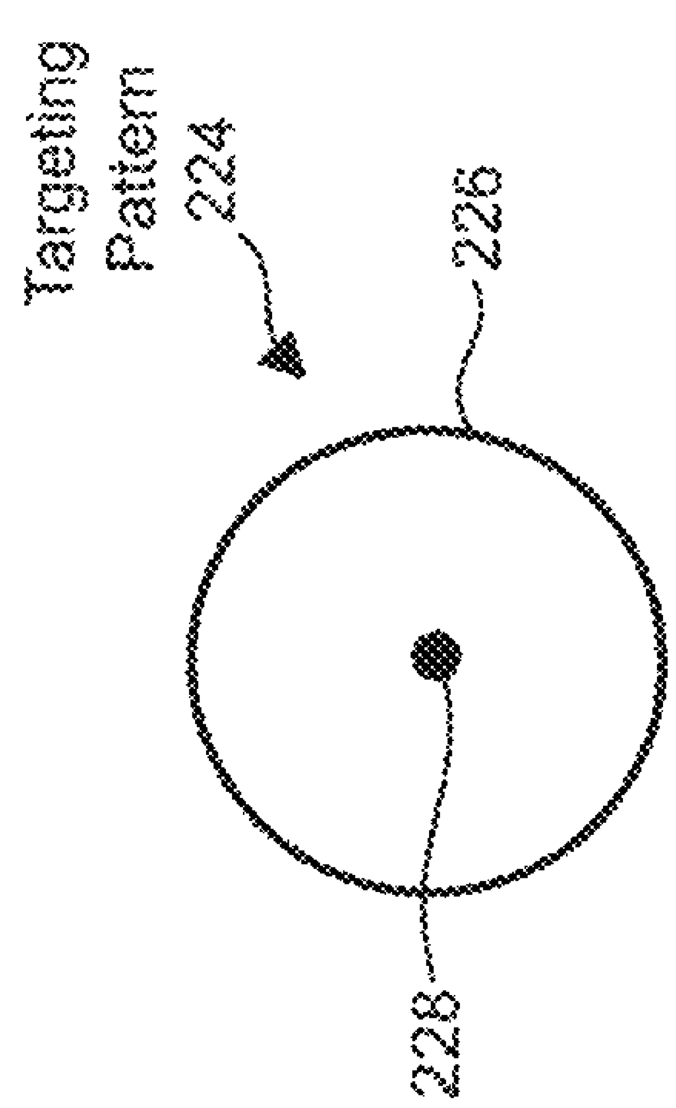


FIG. 8A

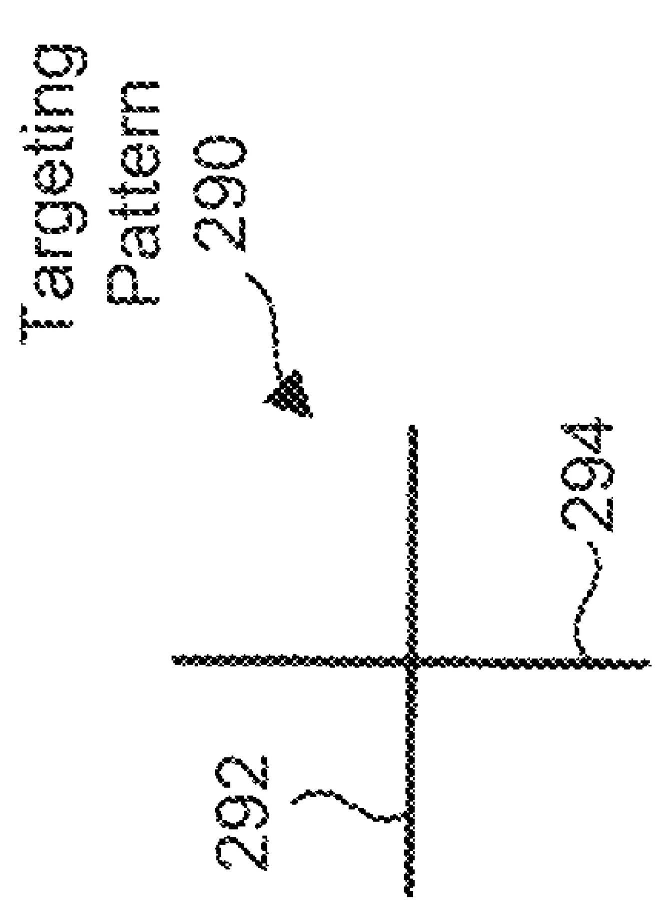


FIG. 8B

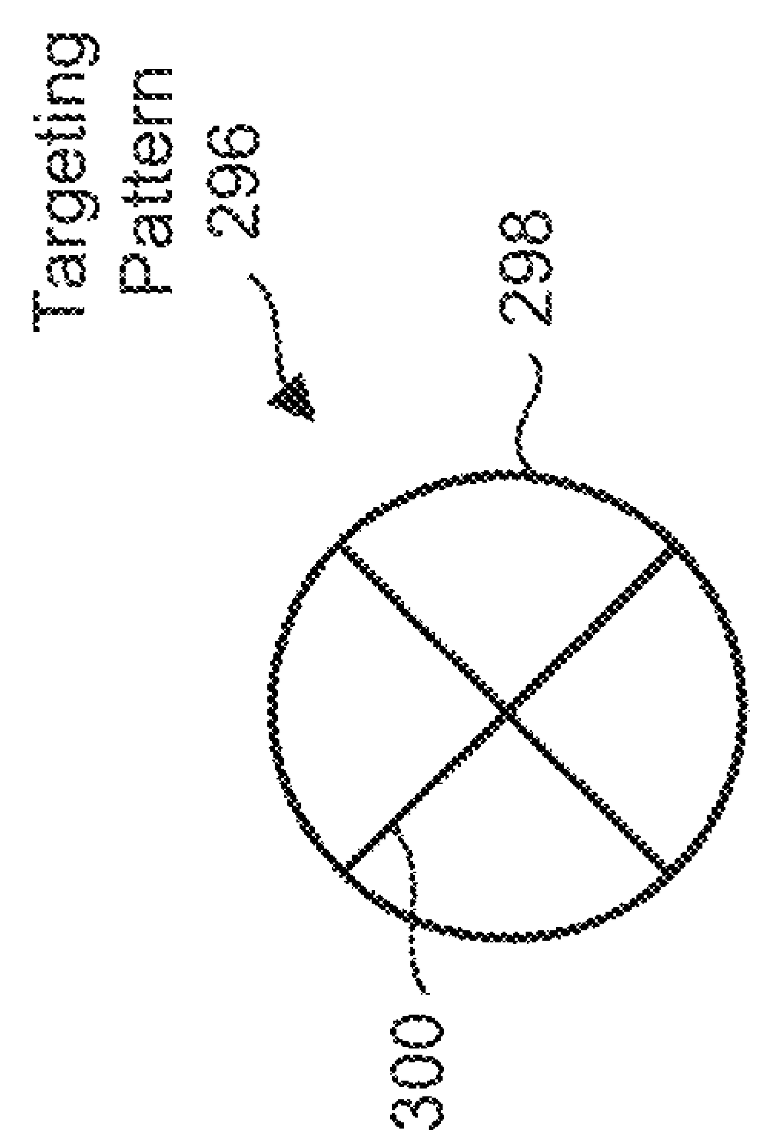


FIG. 8C

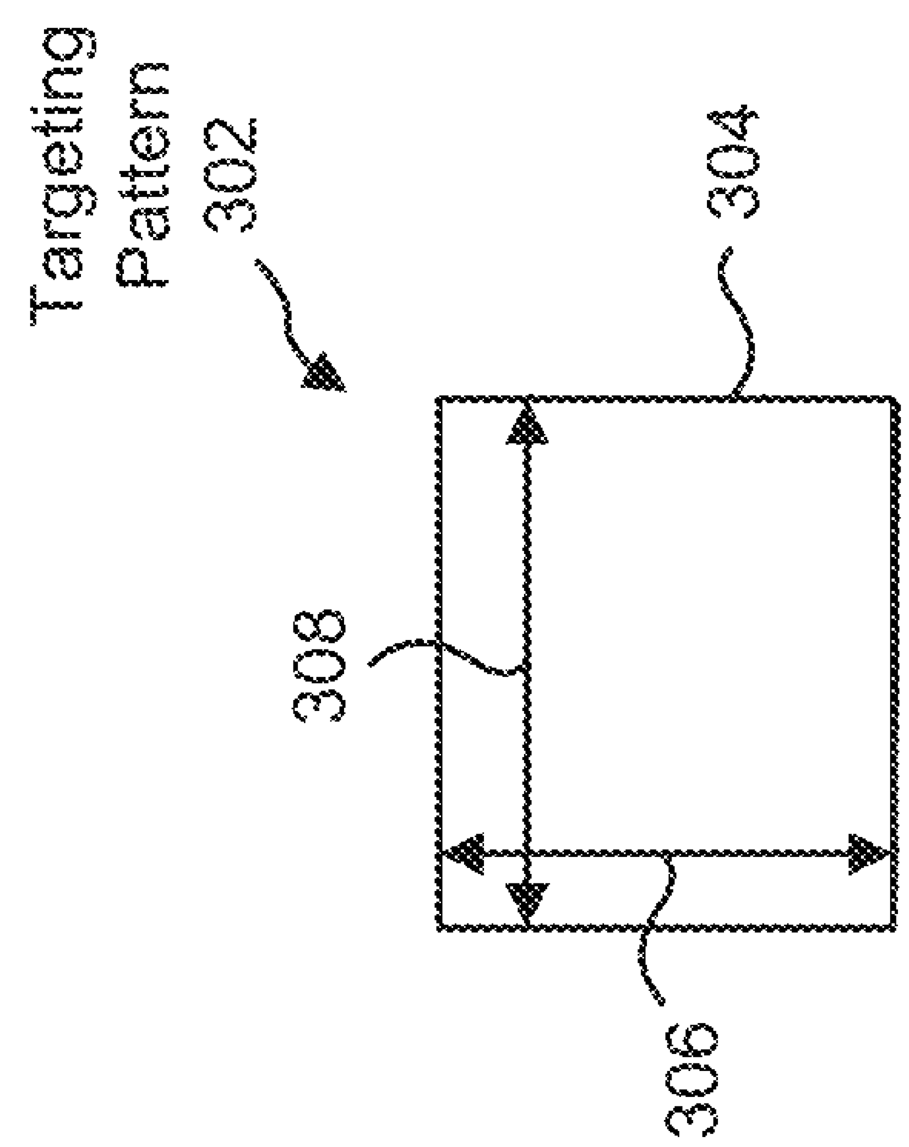


FIG. 8D

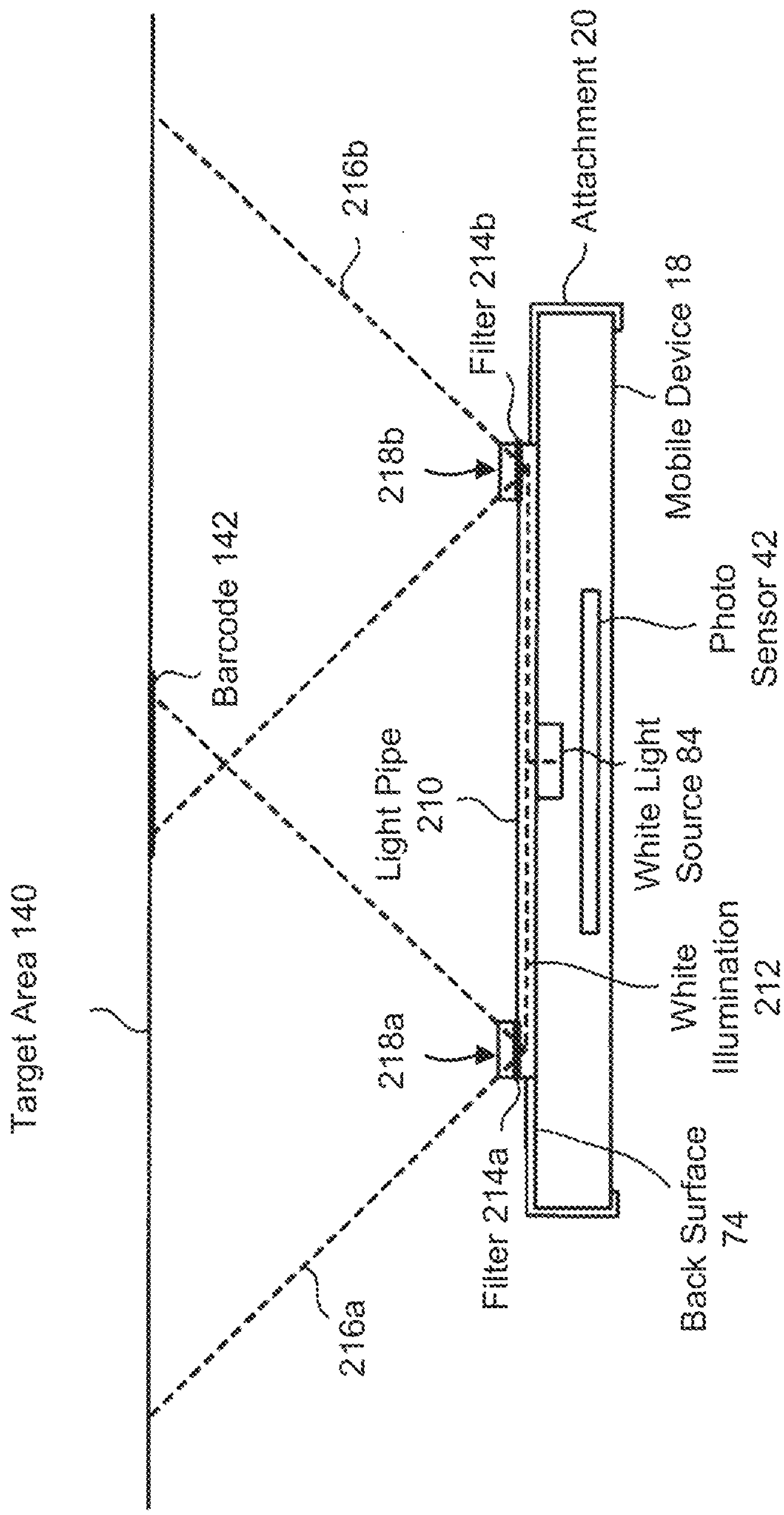

Target Area 140
Barcode 142
216b
216a
Filter 214b
Filter 214a
Attachment 20
Mobile Device 18
218b
218a
Photo Sensor 42
White Light Source 84
Light Pipe 210
White Illumination 212
Back Surface 74

FIG. 9

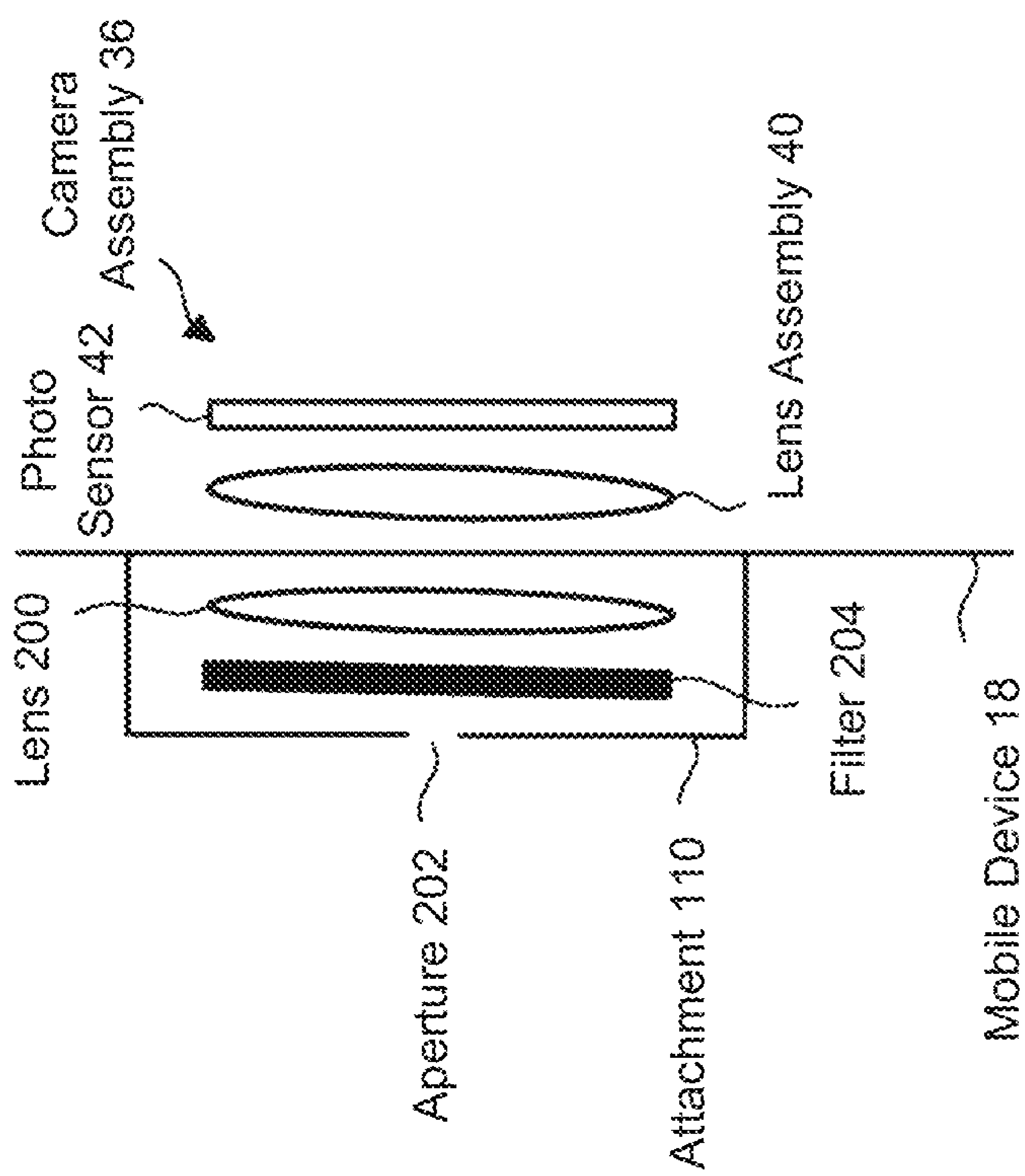


FIG. 10A

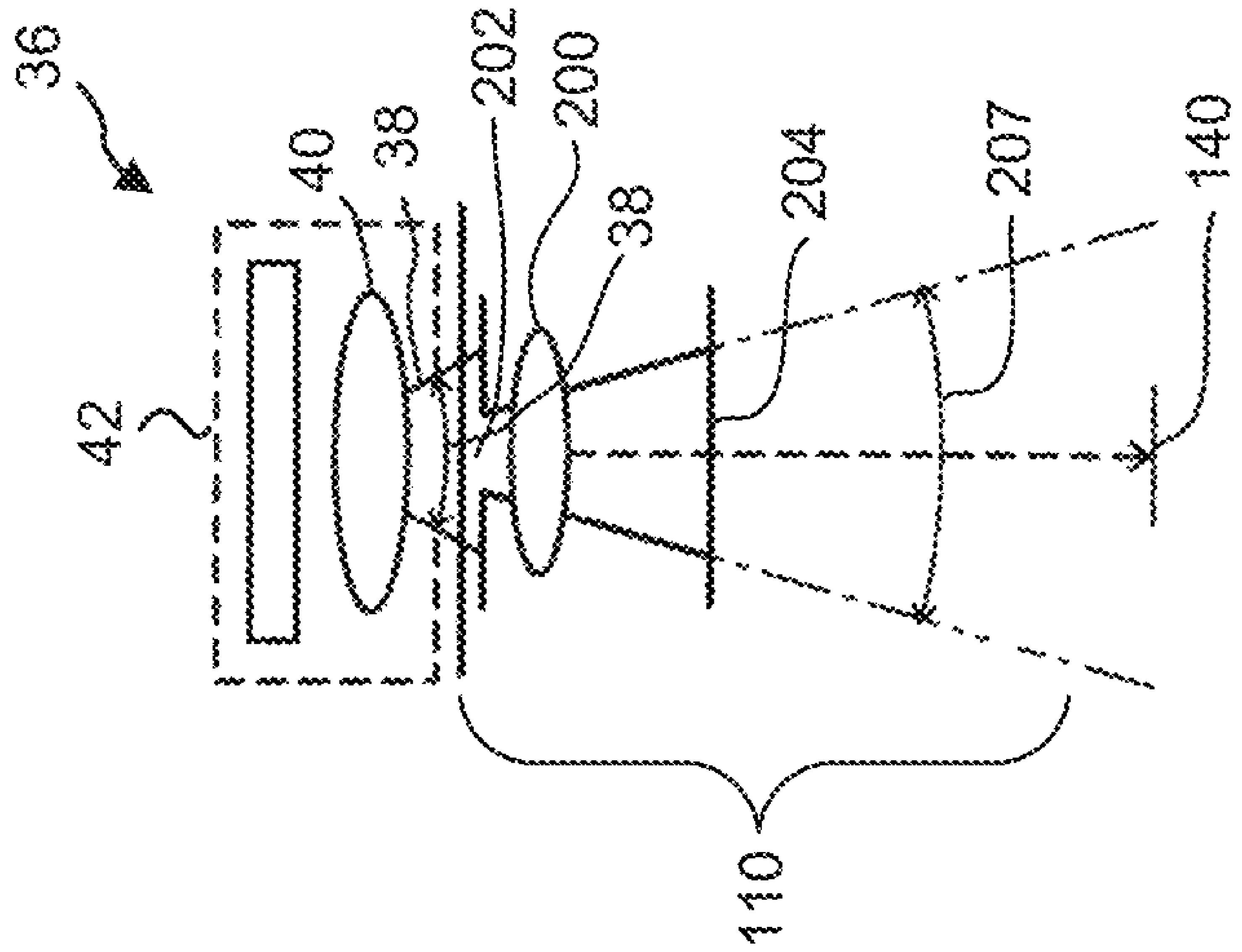


FIG. 10B

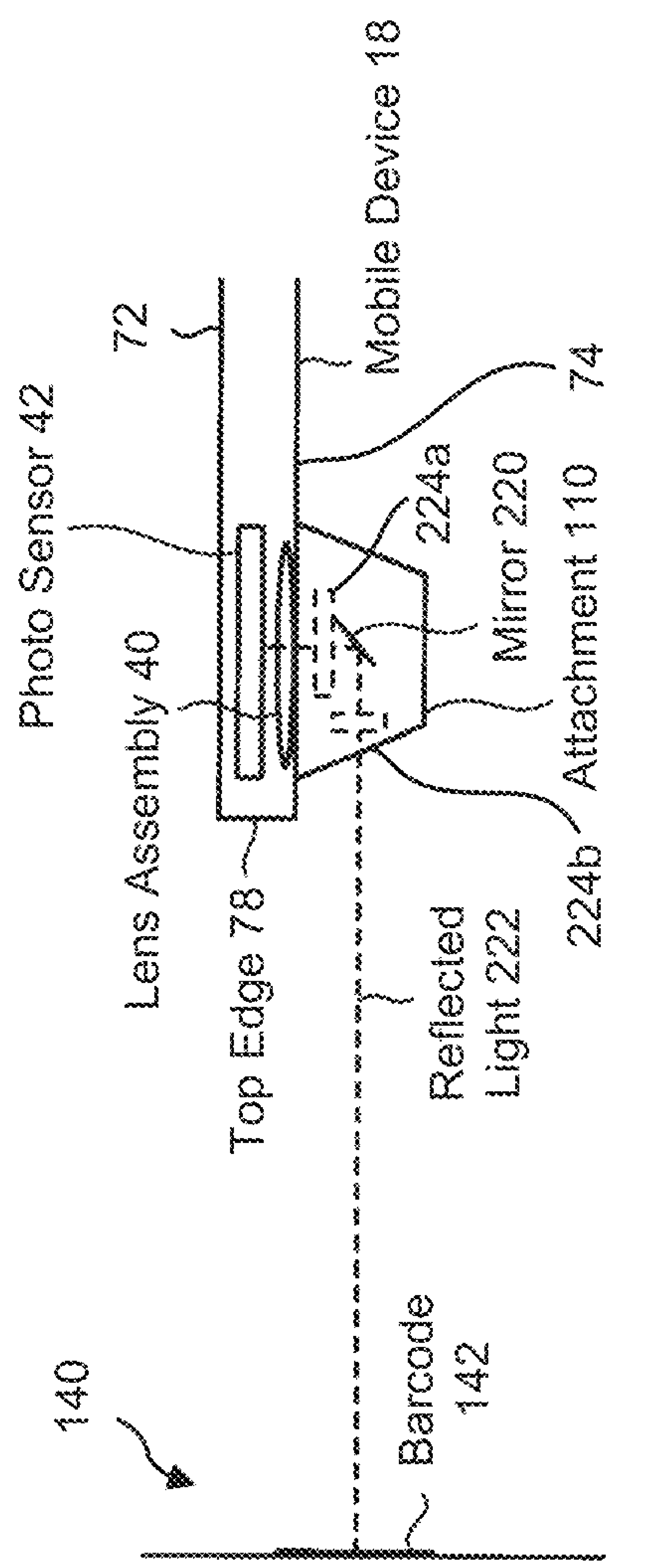

140
Barcode 142
Reflected Light 222
Top Edge 78
Lens Assembly 40
Photo Sensor 42
72
Mobile Device 18
74
224a
Mirror 220
Attachment 110
224b

FIG. 10C

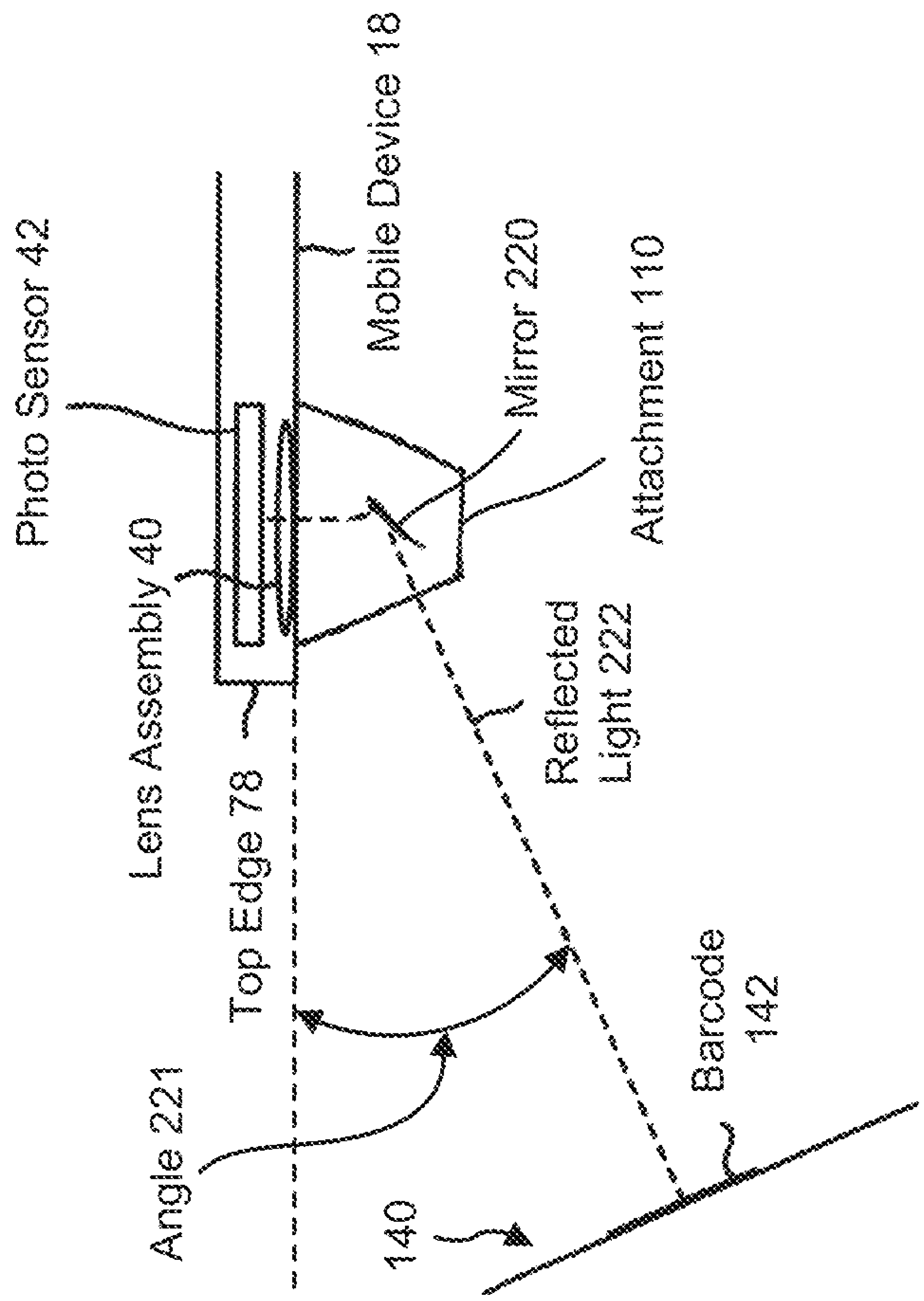


Photo Sensor 42
Lens Assembly 40
Top Edge 78
Angle 221
140
Mobile Device 18
Mirror 220
Attachment 110
Reflected Light 222
Barcode 142

FIG. 10D

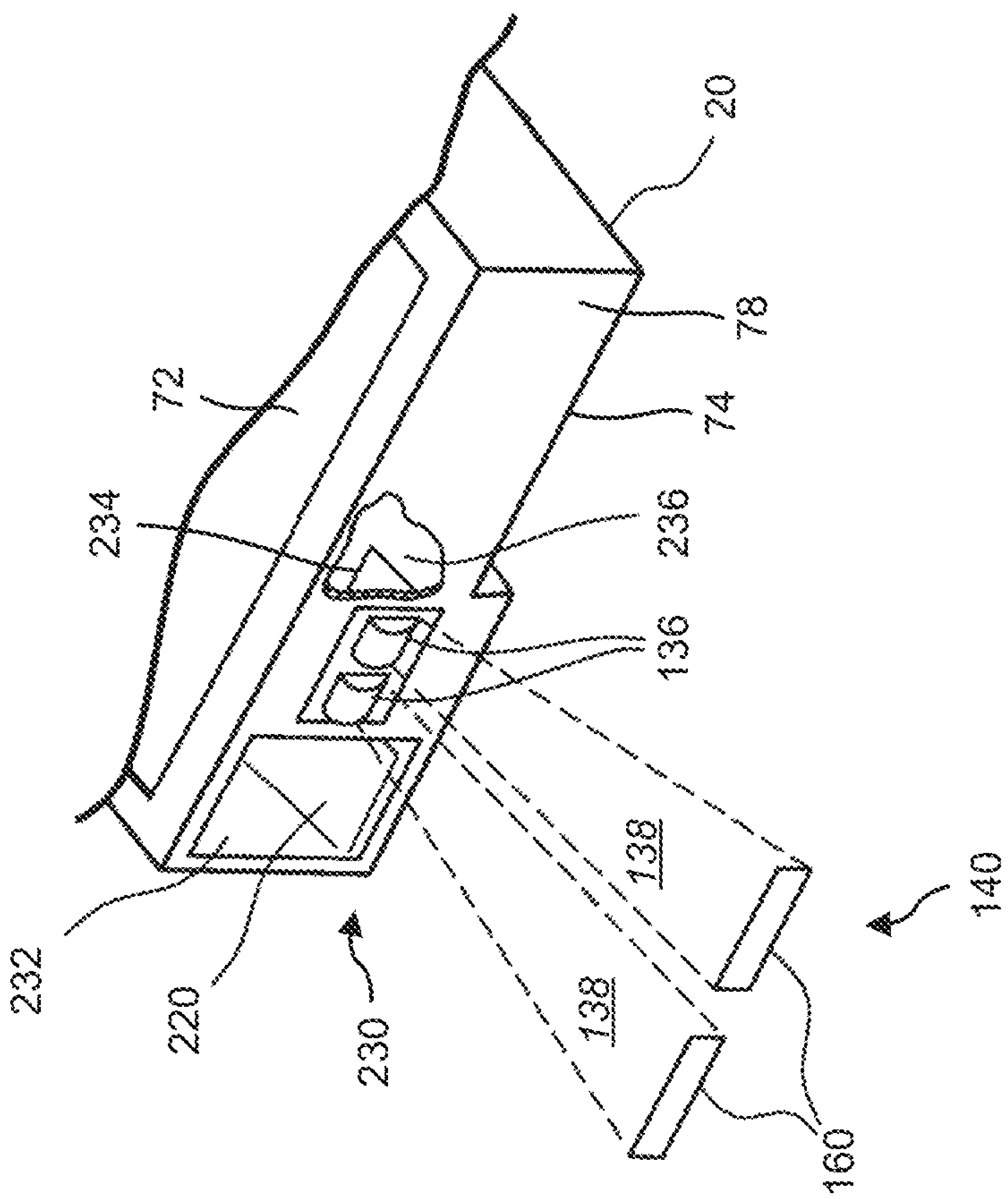


FIG. 11A

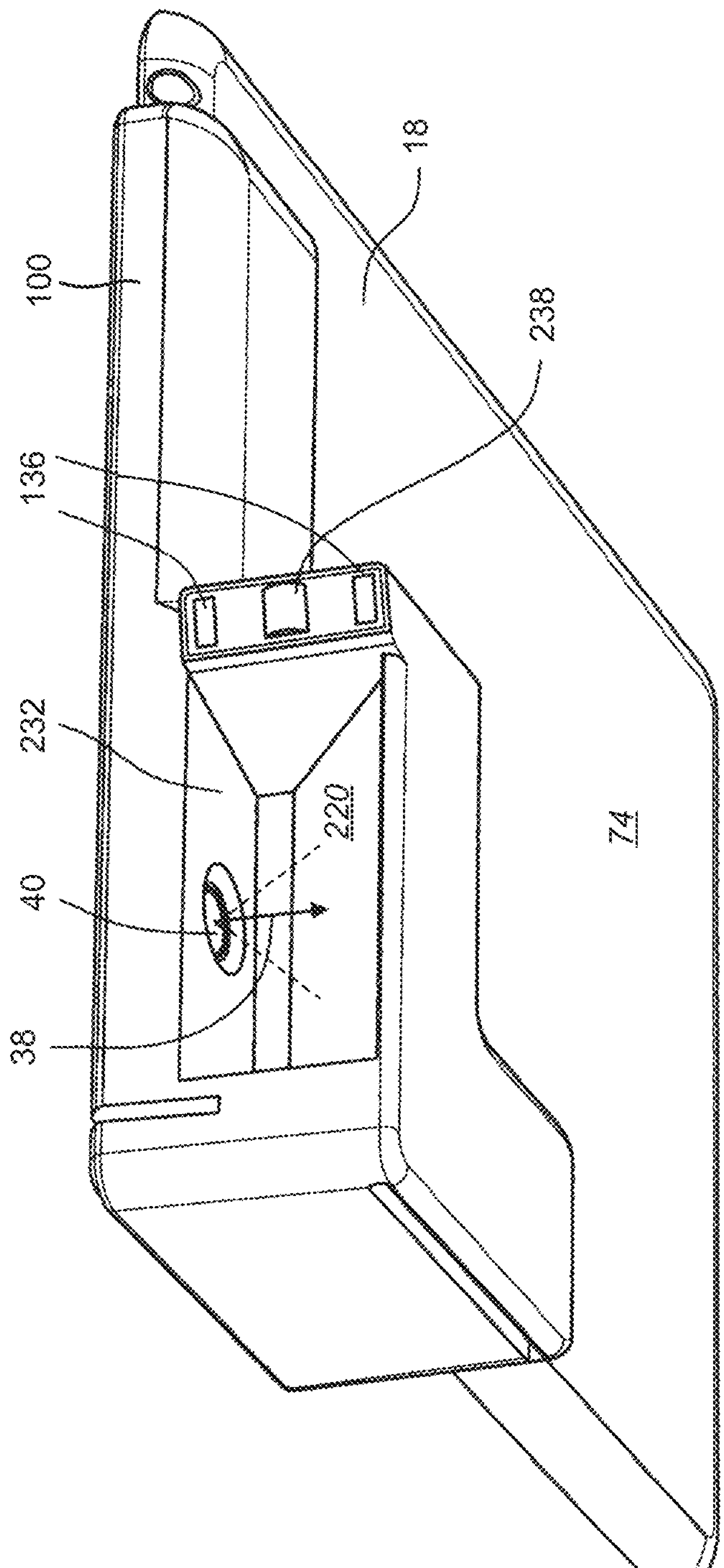


FIG. 11B

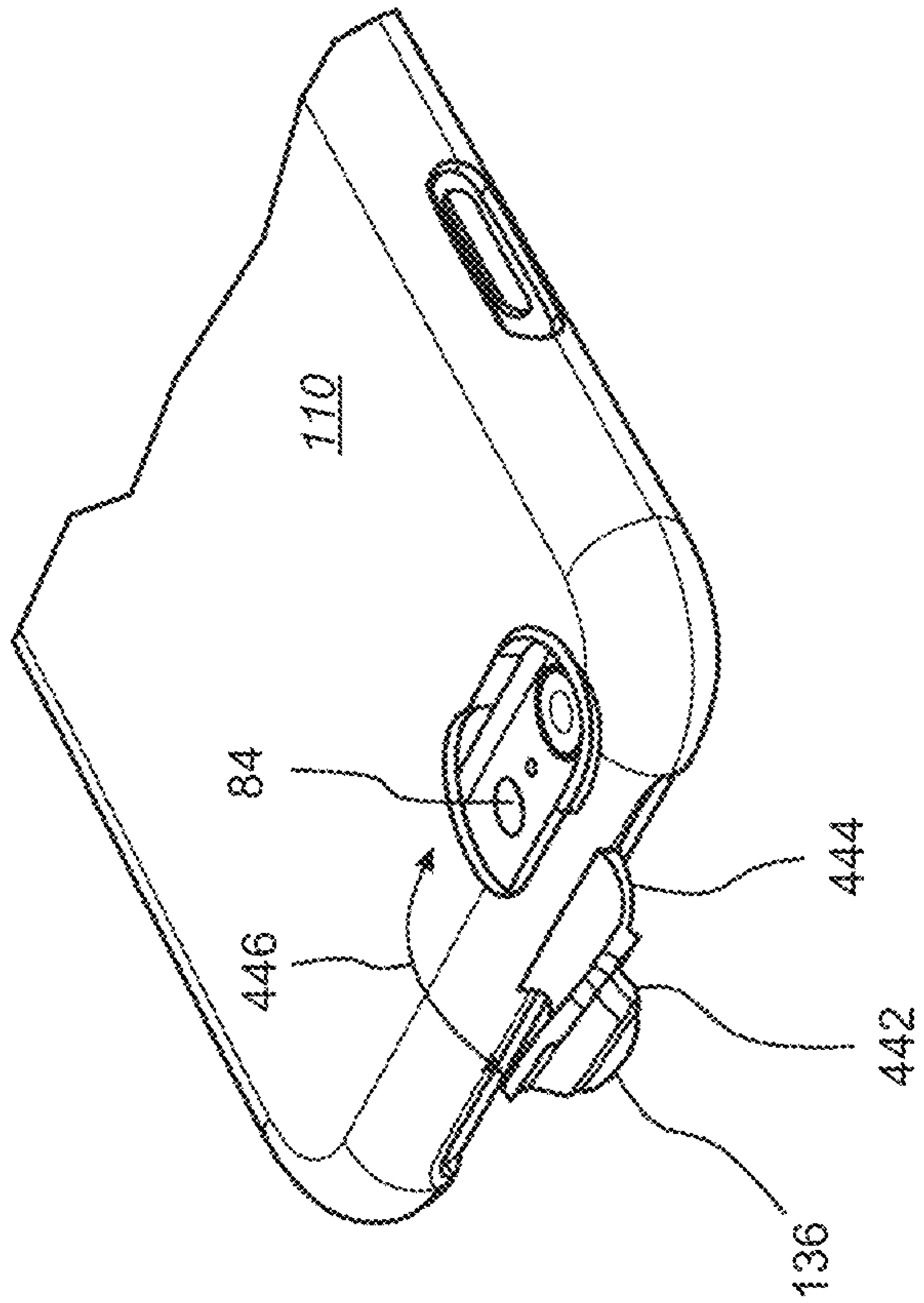


FIG. 12B

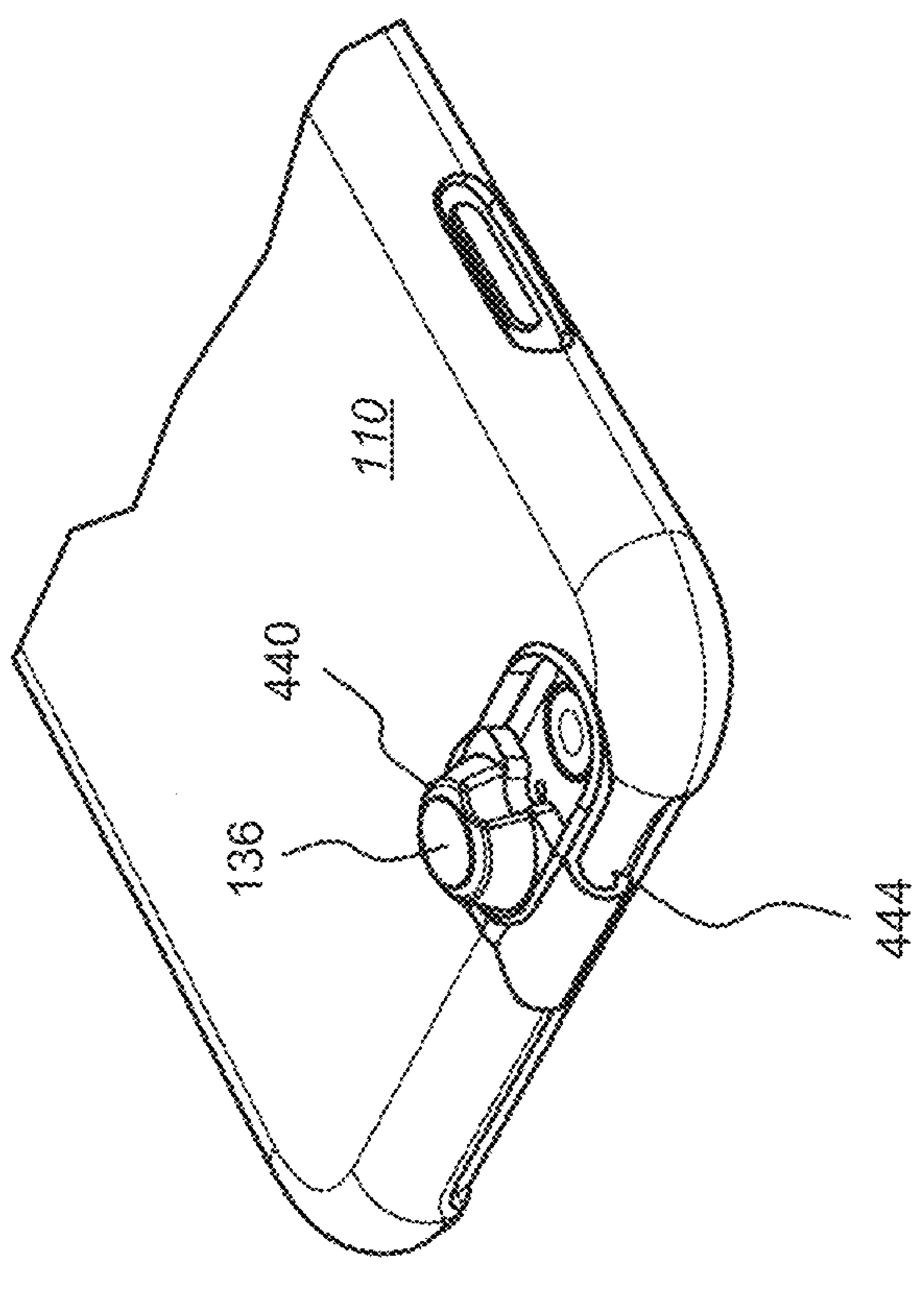


FIG. 12A

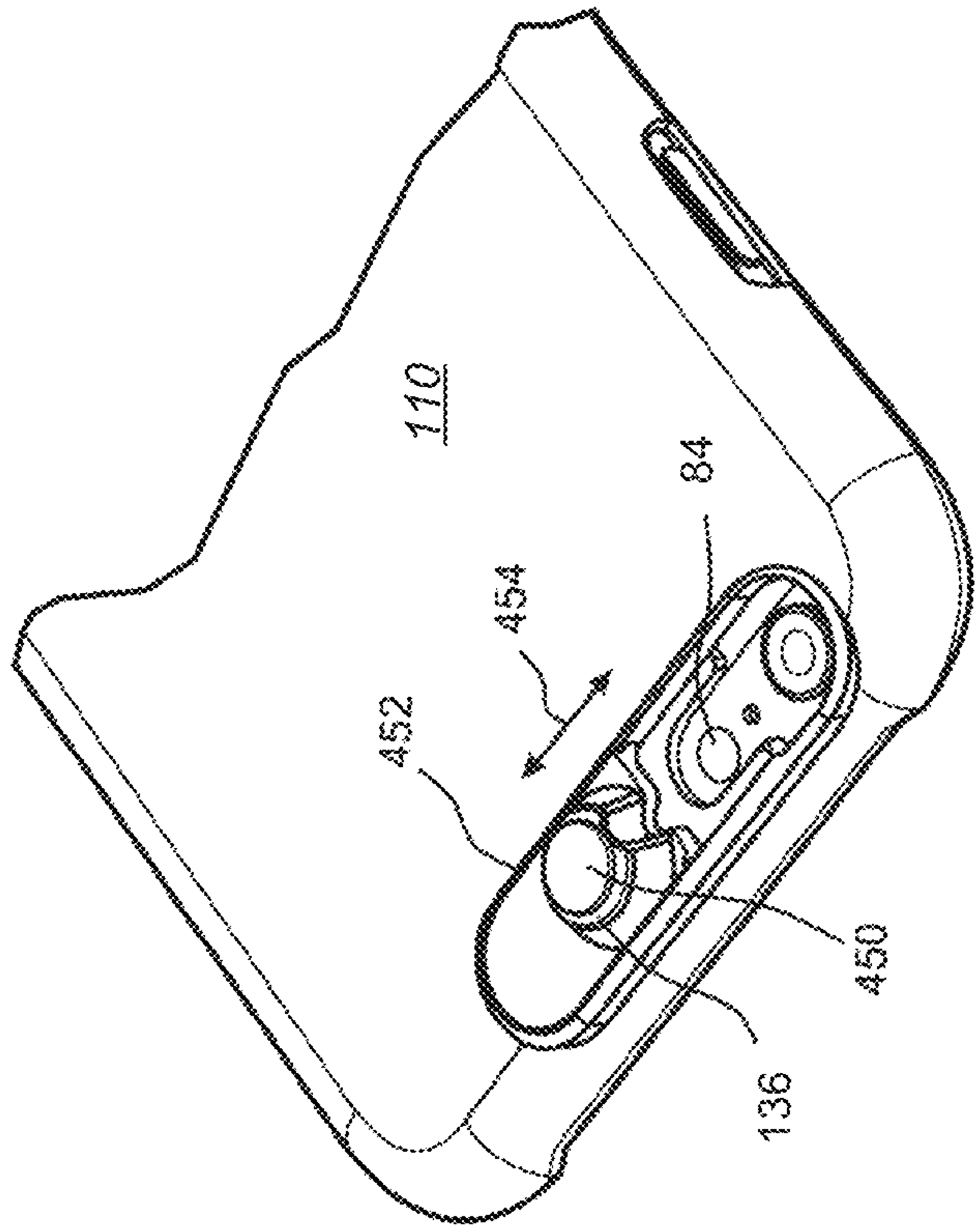


FIG. 12D

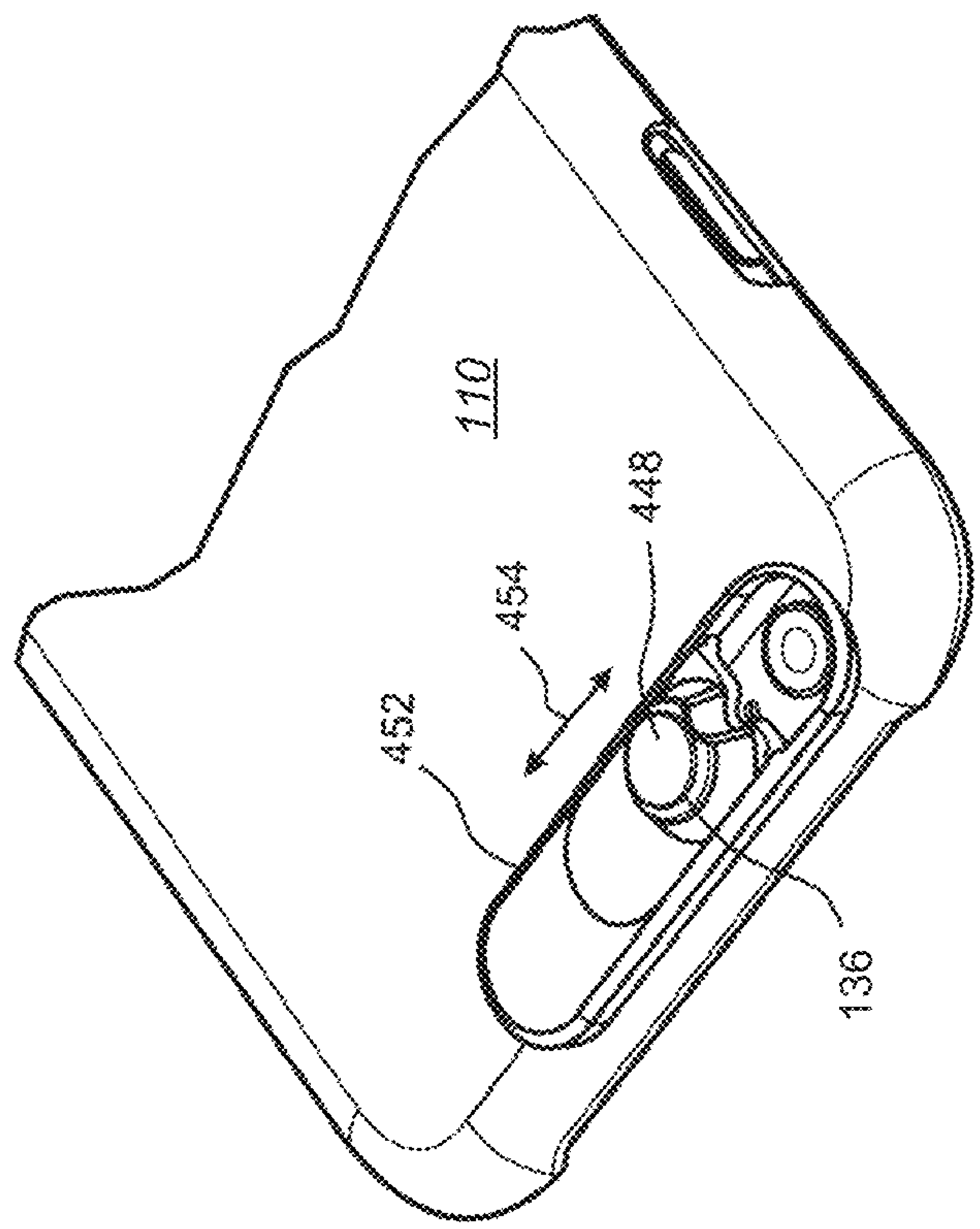


FIG. 12C

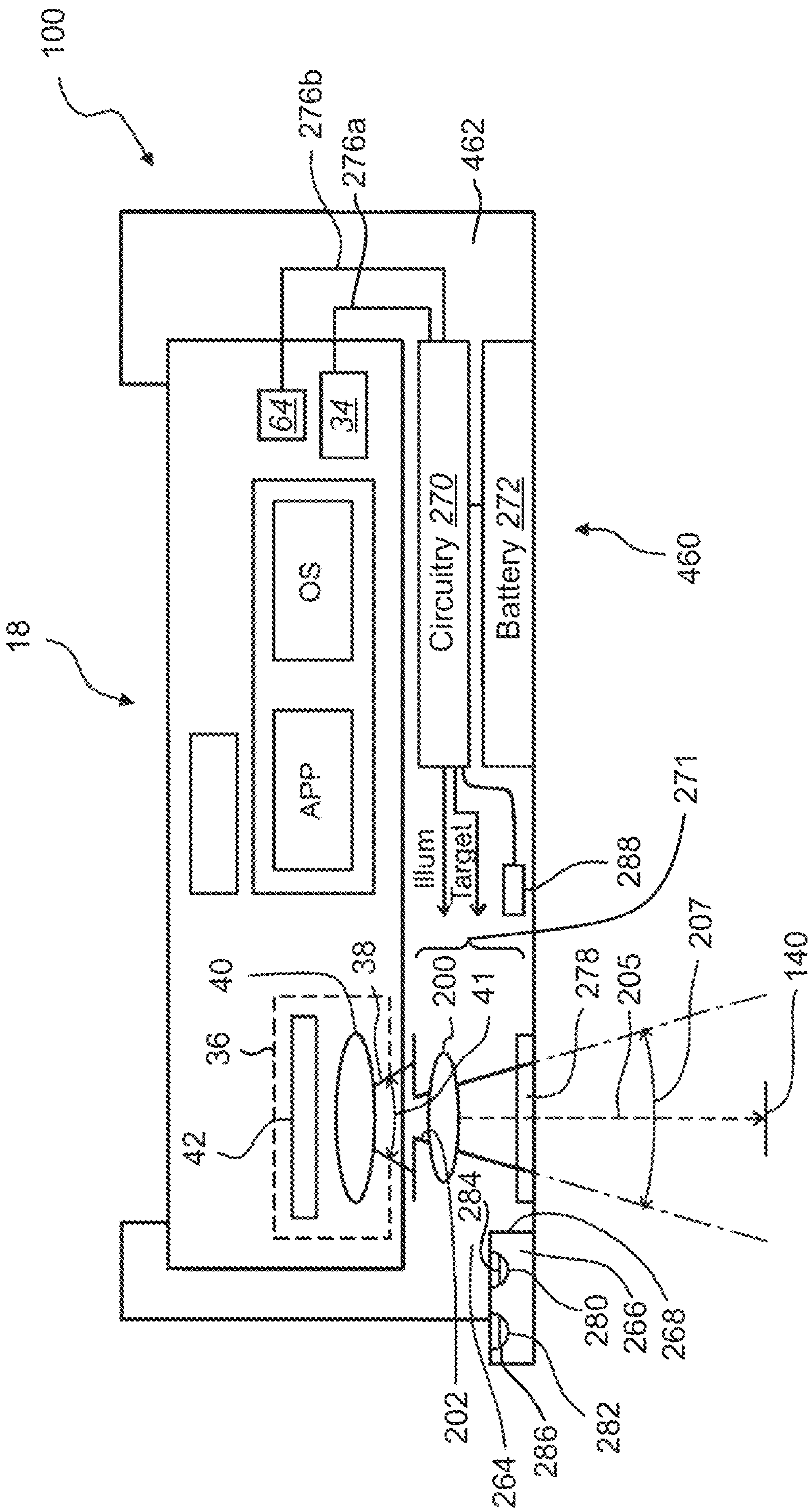

100
276b
276a
462
64
34
Circuitry 270
Battery 272
460
18
OS
APP
Illum
Target
288
271
200
41
40
38
36
42
278
205
207
140
284
280
266
268
202
264
286
282

FIG. 13

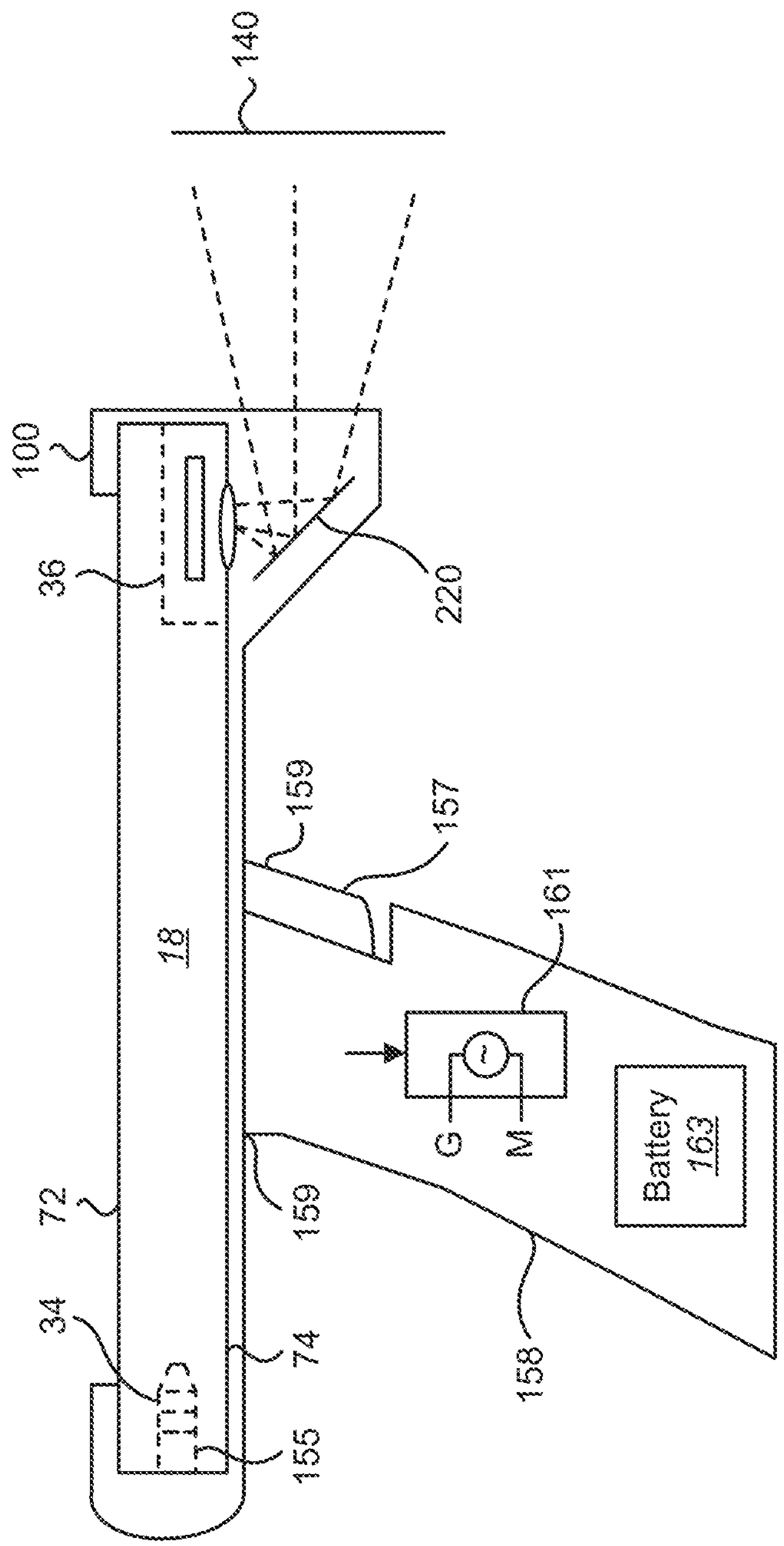


FIG. 14

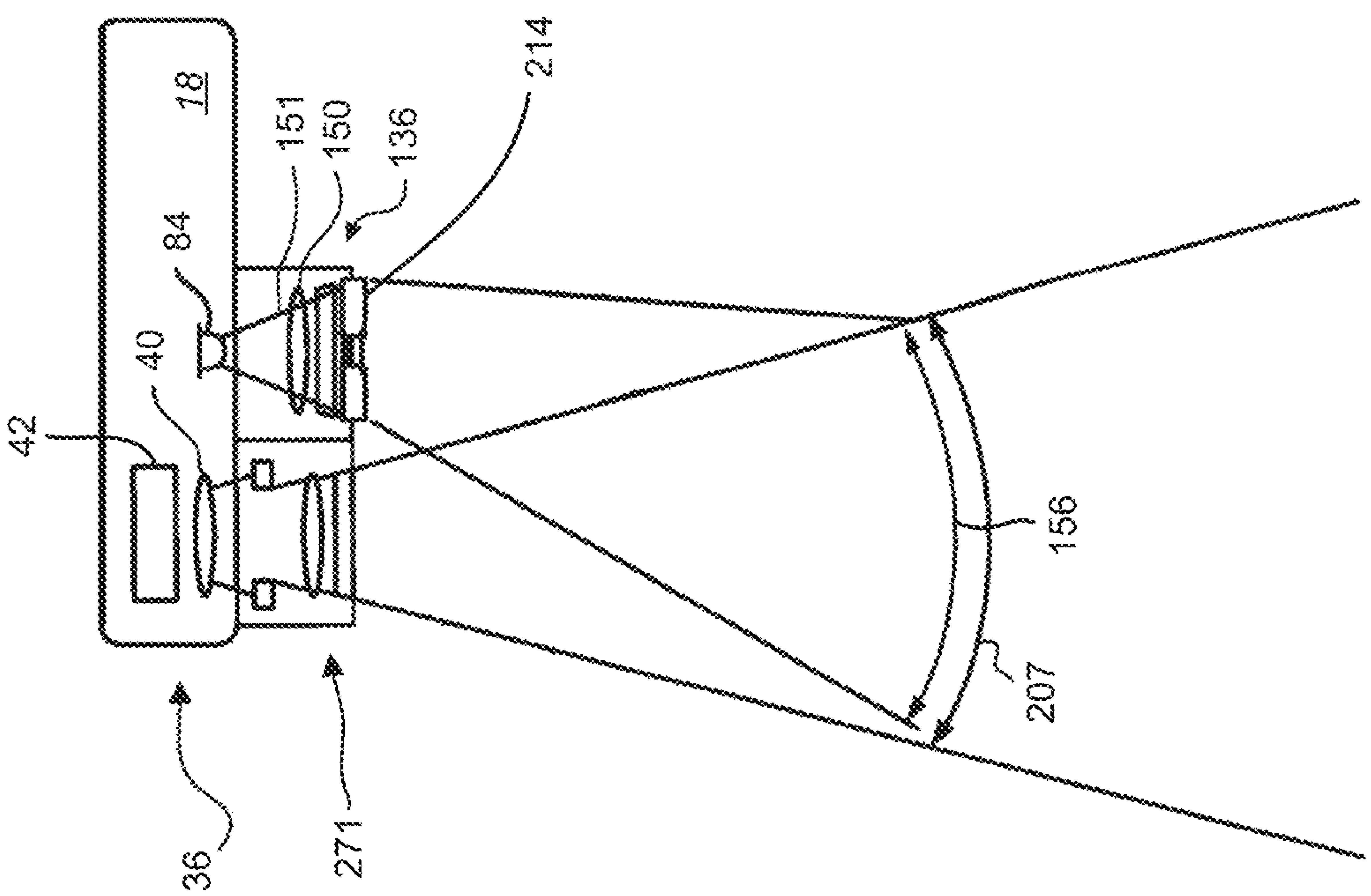


FIG. 15

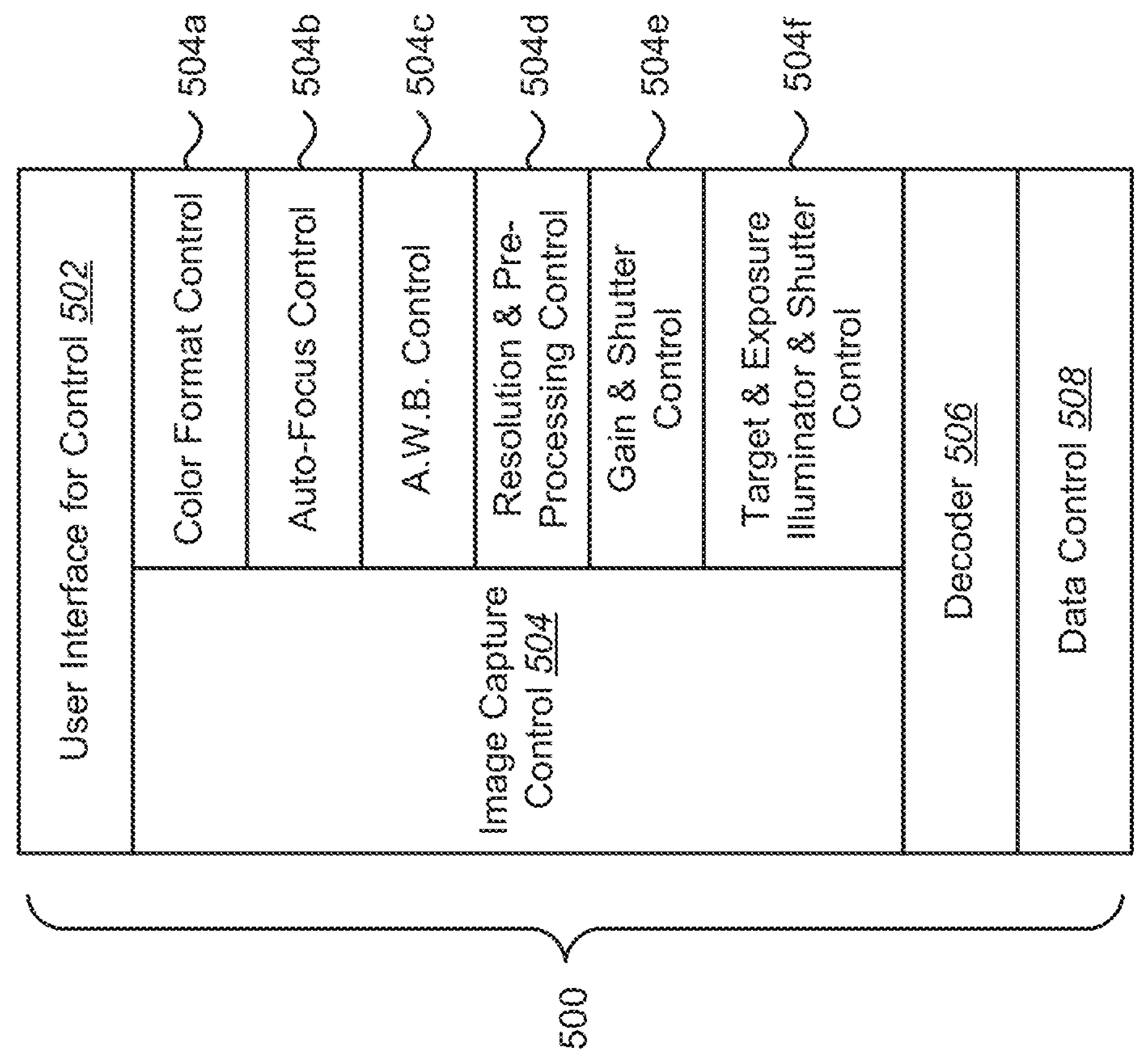

504a
504b
504c
504d
504e
504f
User Interface for Control 502
Color Format Control
Auto-Focus Control
A.W.B. Control
Resolution & Pre-Processing Control
Gain & Shutter Control
Target & Exposure Illuminator & Shutter Control
Image Capture Control 504
Decoder 506
Data Control 508
500

FIG. 16

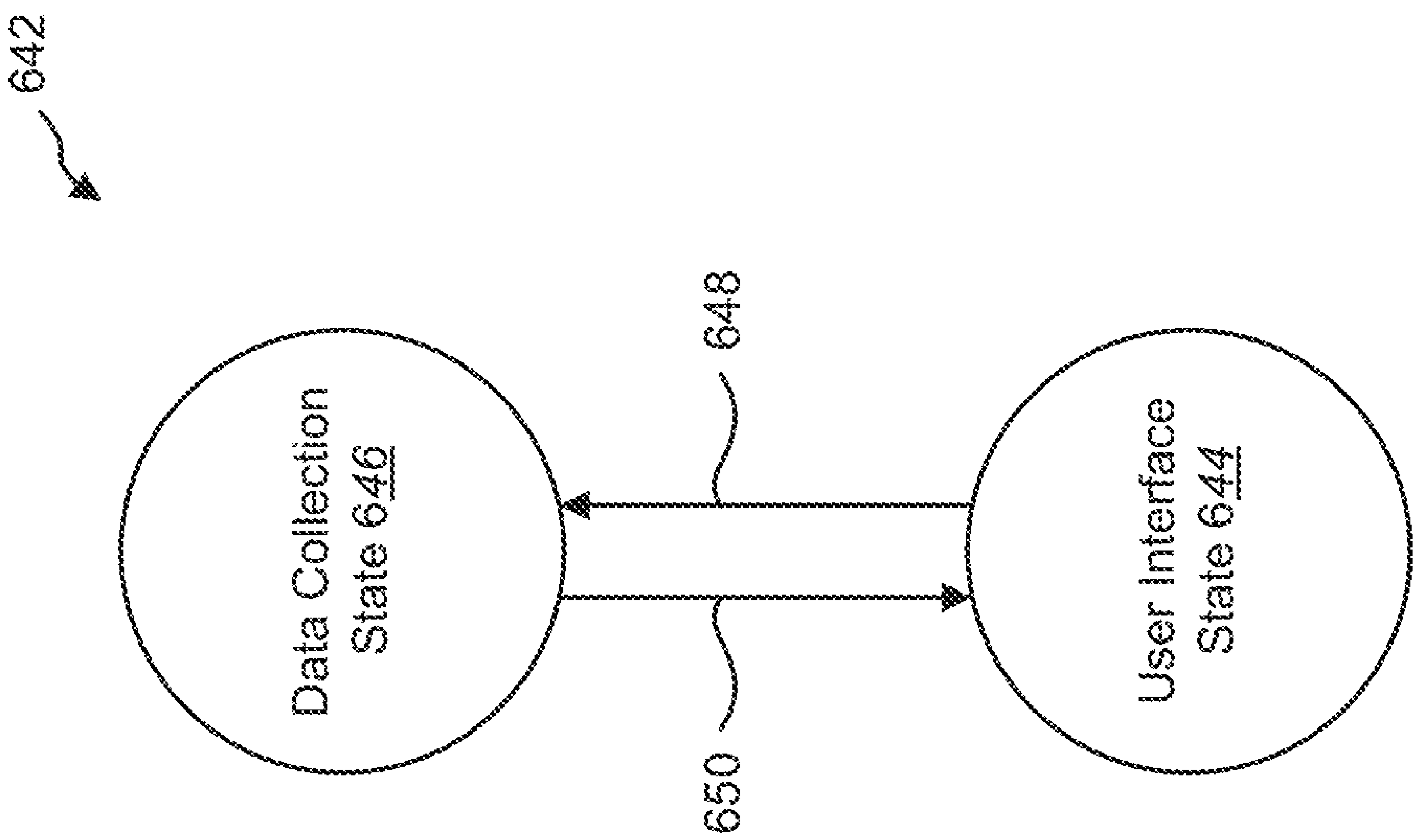

642
Data Collection
State 646
648
650
User Interface
State 644

FIG. 17

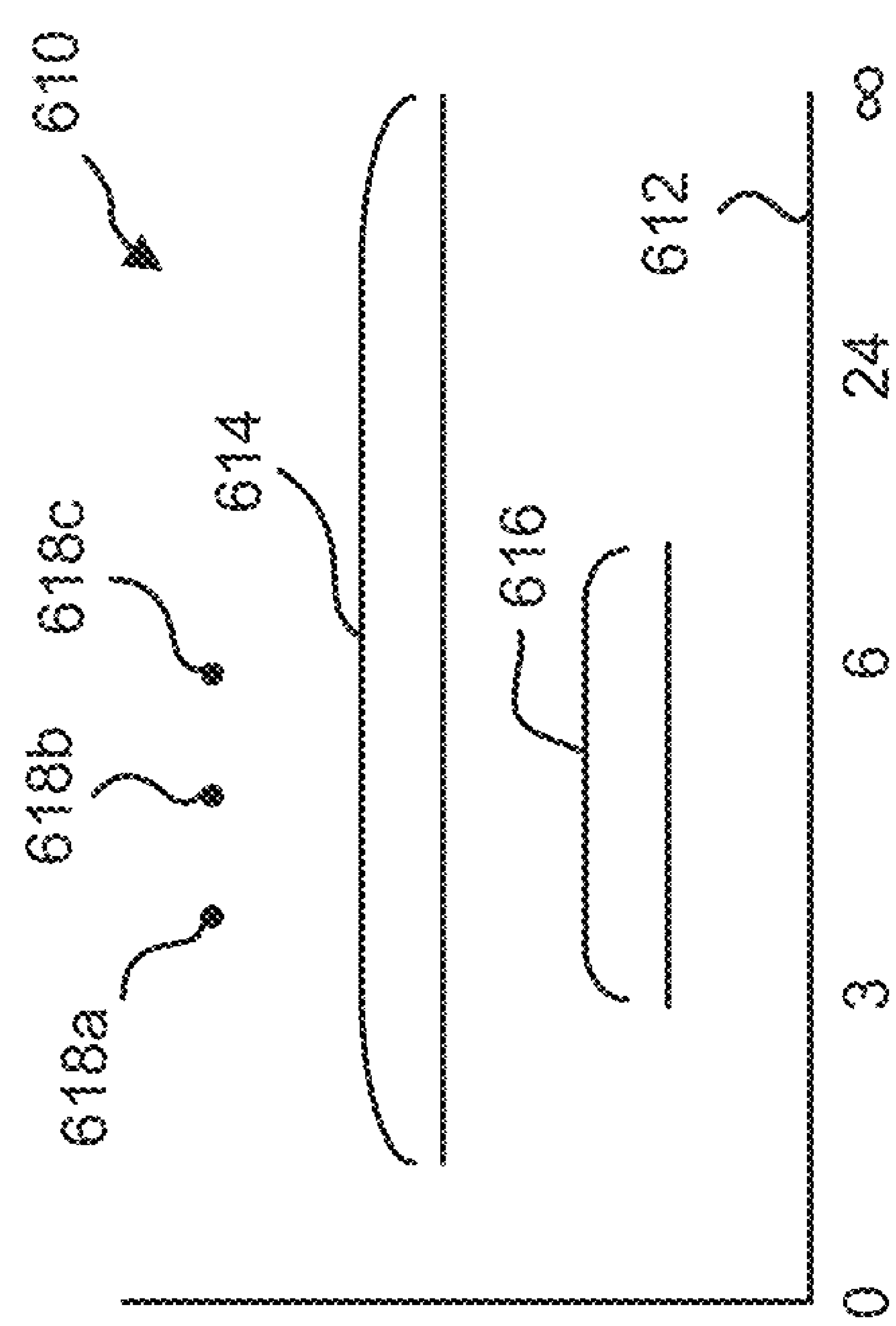


FIG. 18A

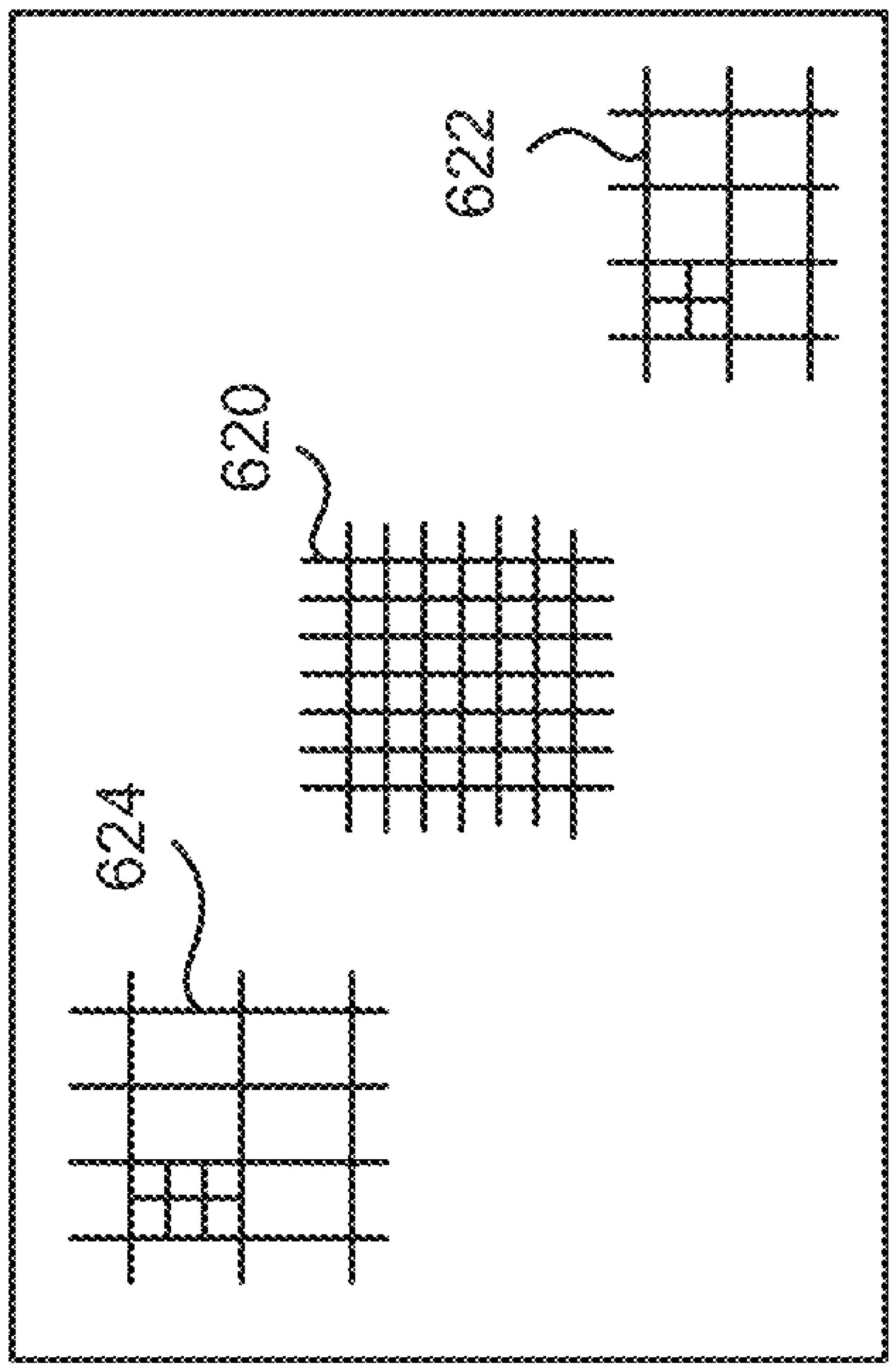


FIG. 18B

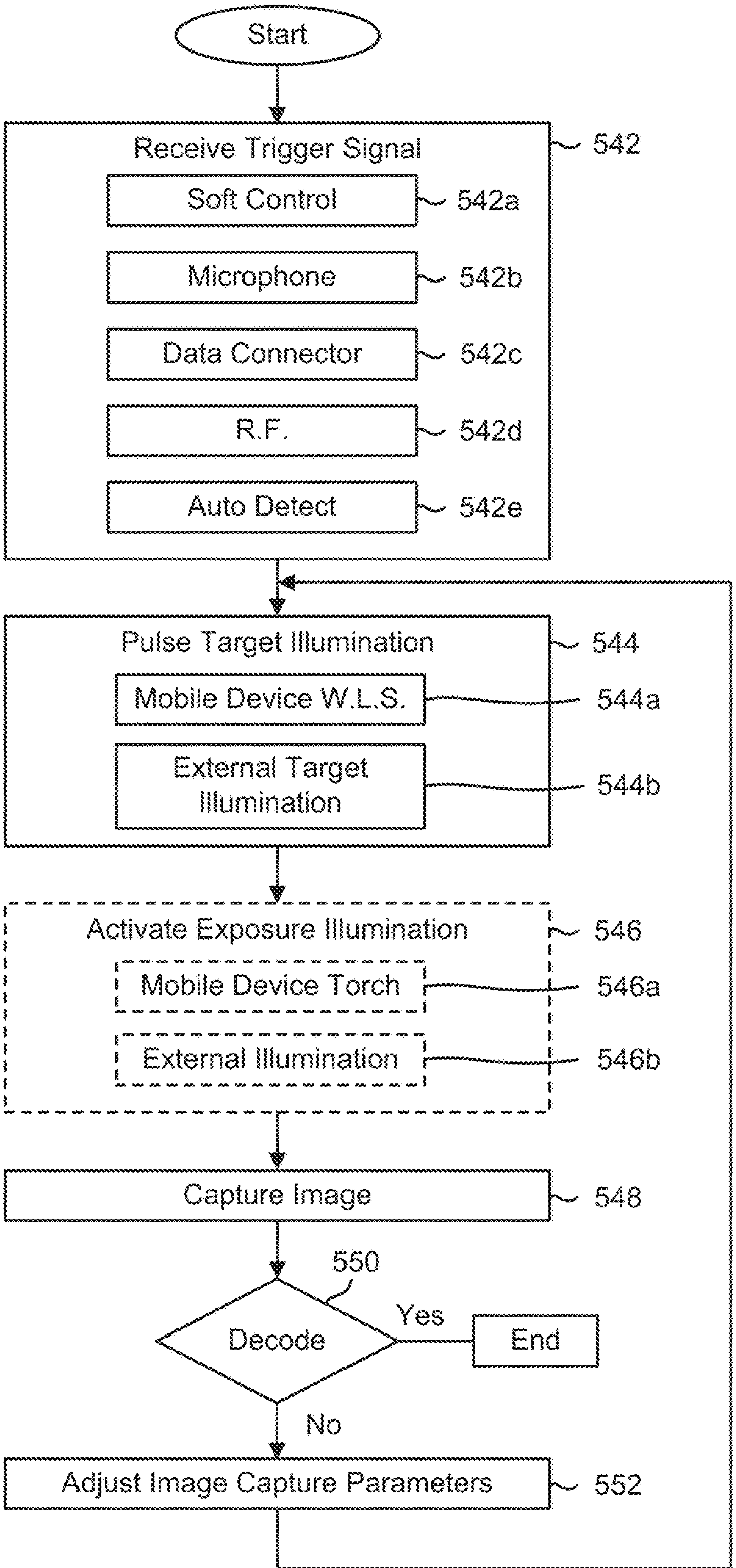

Start
Receive Trigger Signal
542
Soft Control
542a
Microphone
542b
Data Connector
542c
R.F.
542d
Auto Detect
542e
Pulse Target Illumination
544
Mobile Device W.L.S.
544a
External Target Illumination
544b
Activate Exposure Illumination
546
Mobile Device Torch
546a
External Illumination
546b
Capture Image
548
550
Decode
Yes
End
No
Adjust Image Capture Parameters
552

FIG. 19A

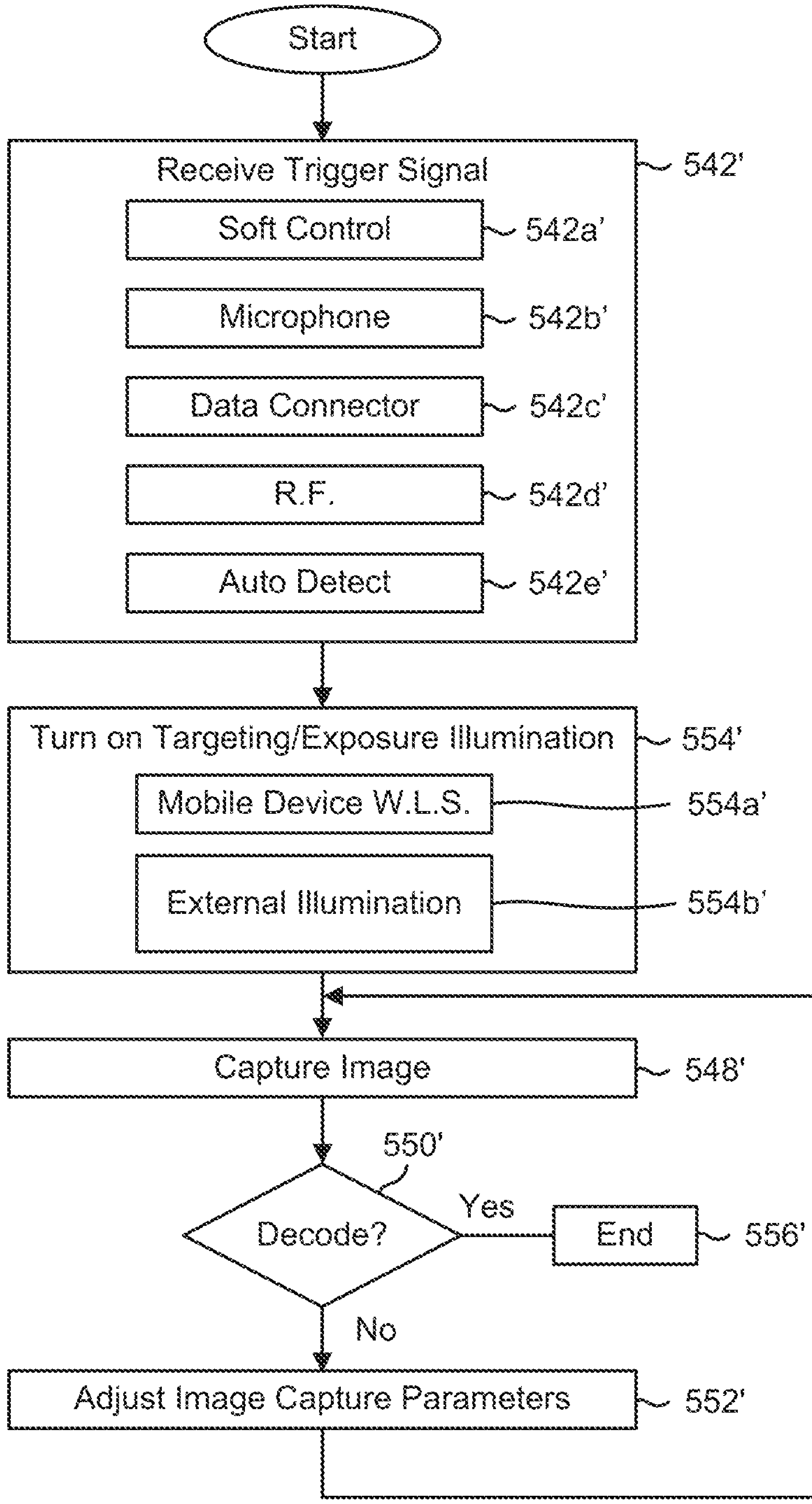

Start
Receive Trigger Signal
542'
Soft Control
542a'
Microphone
542b'
Data Connector
542c'
R.F.
542d'
Auto Detect
542e'
Turn on Targeting/Exposure Illumination
554'
Mobile Device W.L.S.
554a'
External Illumination
554b'
Capture Image
548'
550'
Decode?
Yes
End
556'
No
Adjust Image Capture Parameters
552'

FIG. 19B

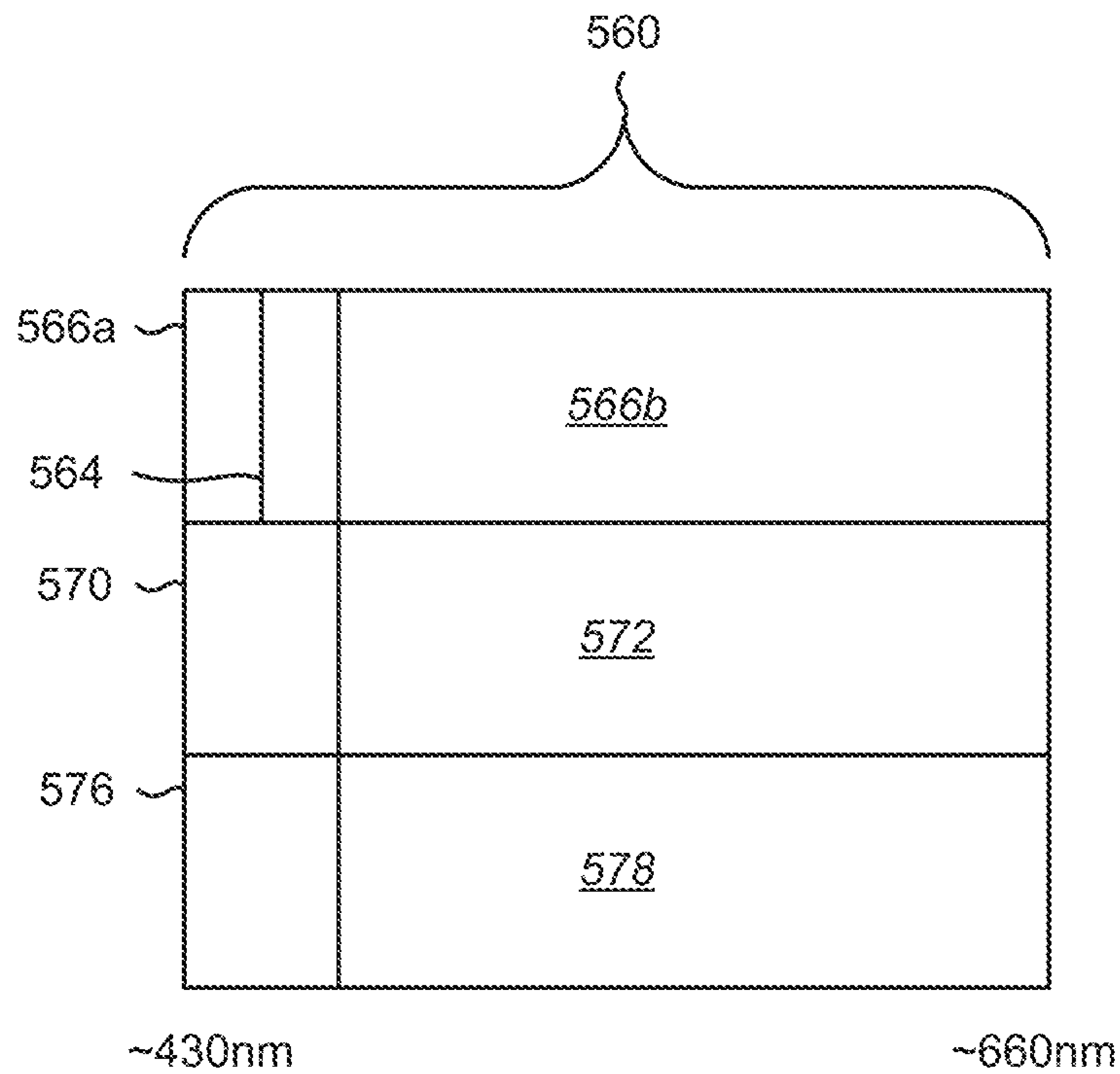


FIG. 19C

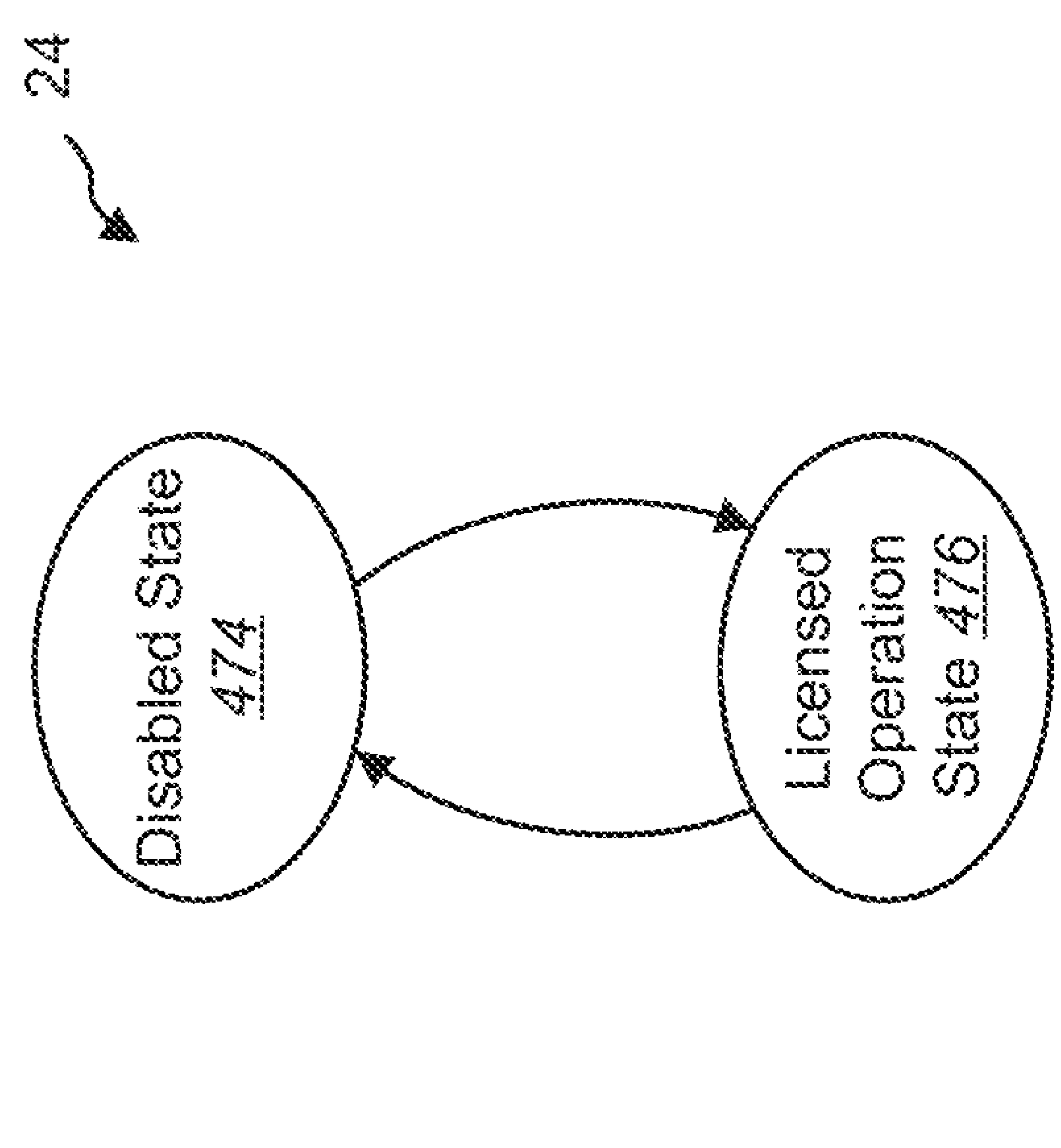


FIG. 20A

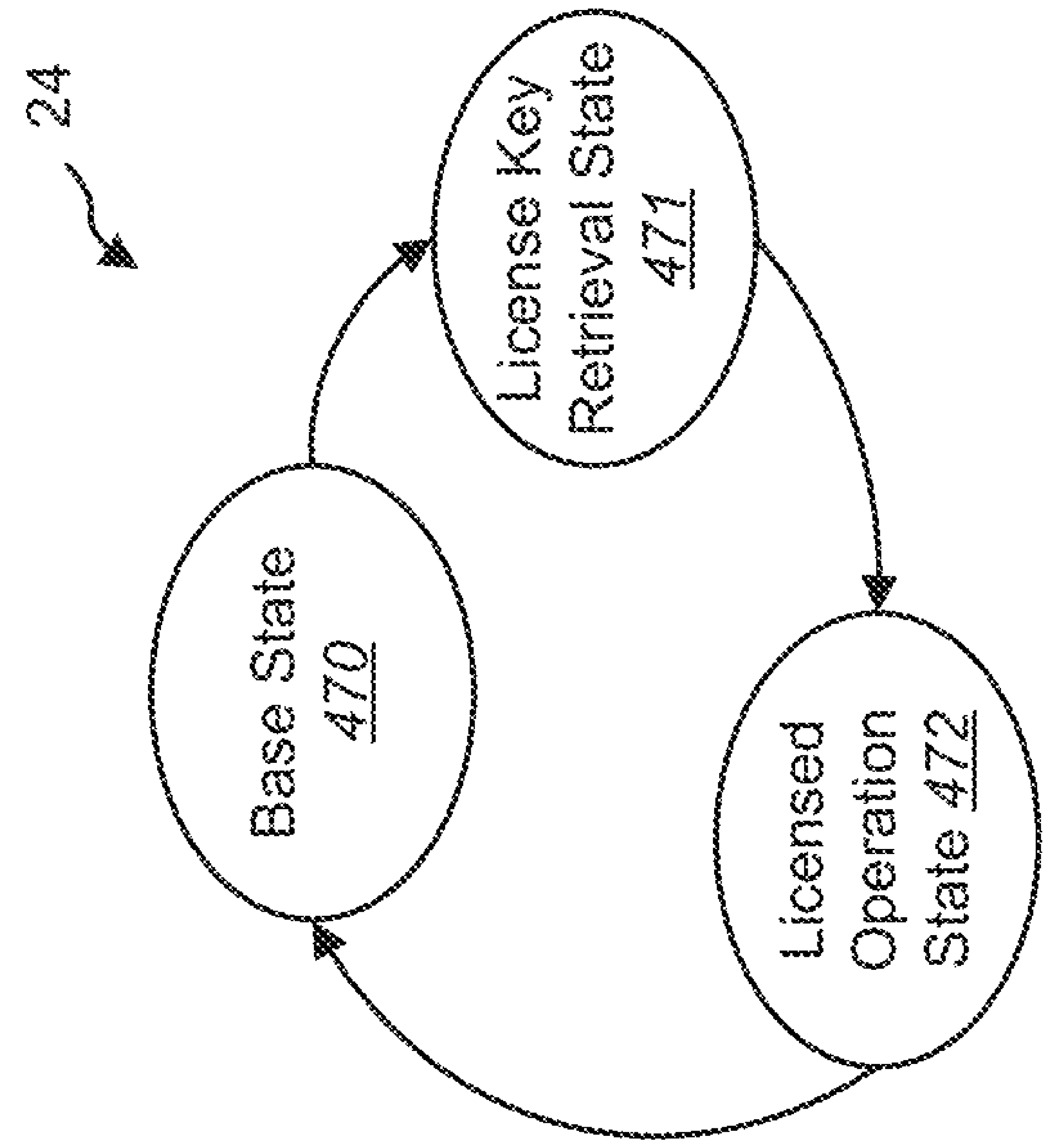


FIG. 20B

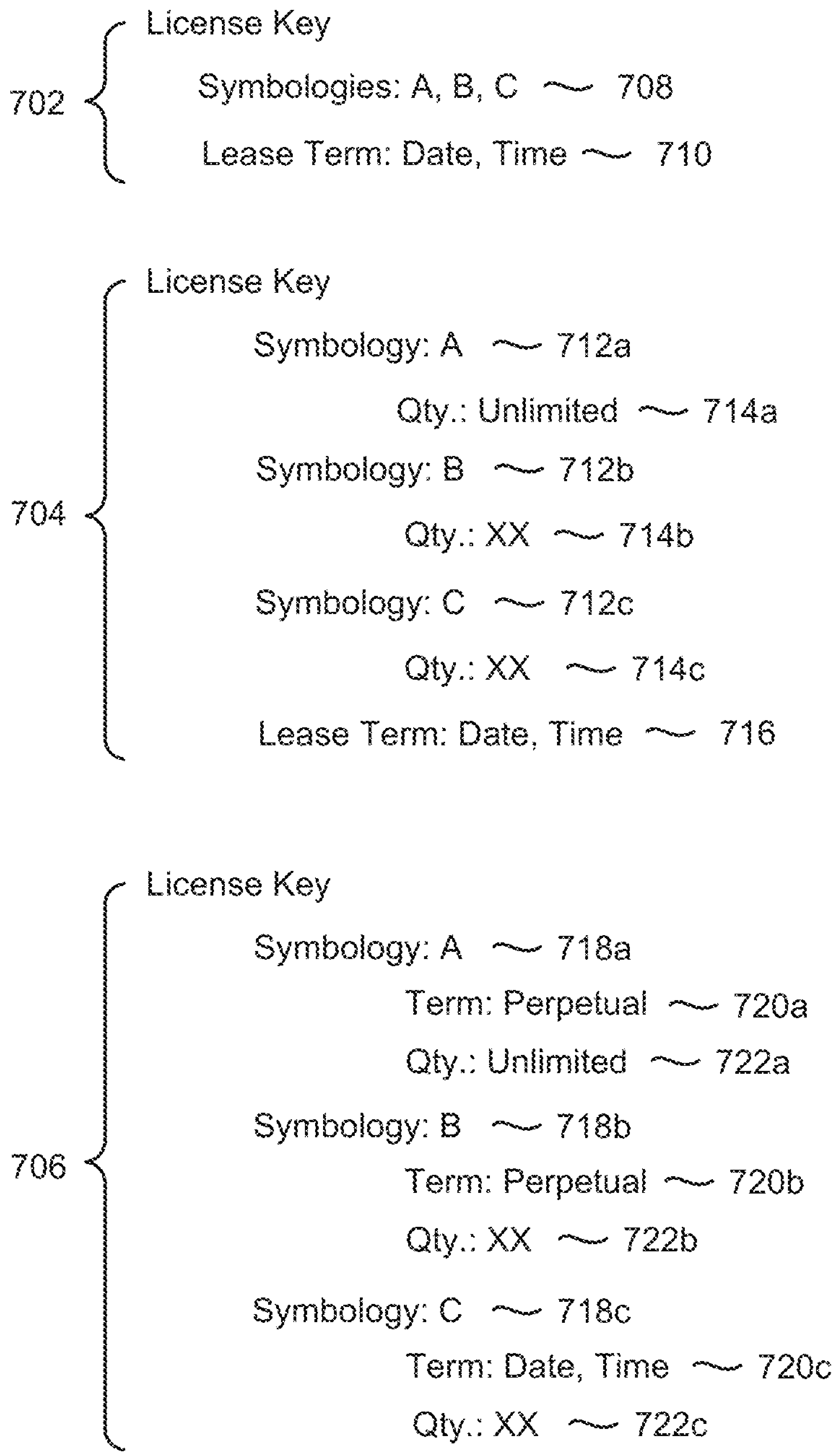

702
License Key
Symbologies: A, B, C 708
Lease Term: Date, Time 710
704
License Key
Symbology: A 712a
Qty.: Unlimited 714a
Symbology: B 712b
Qty.: XX 714b
Symbology: C 712c
Qty.: XX 714c
Lease Term: Date, Time 716
706
License Key
Symbology: A 718a
Term: Perpetual 720a
Qty.: Unlimited 722a
Symbology: B 718b
Term: Perpetual 720b
Qty.: XX 722b
Symbology: C 718c
Term: Date, Time 720c
Qty.: XX 722c

FIG. 21

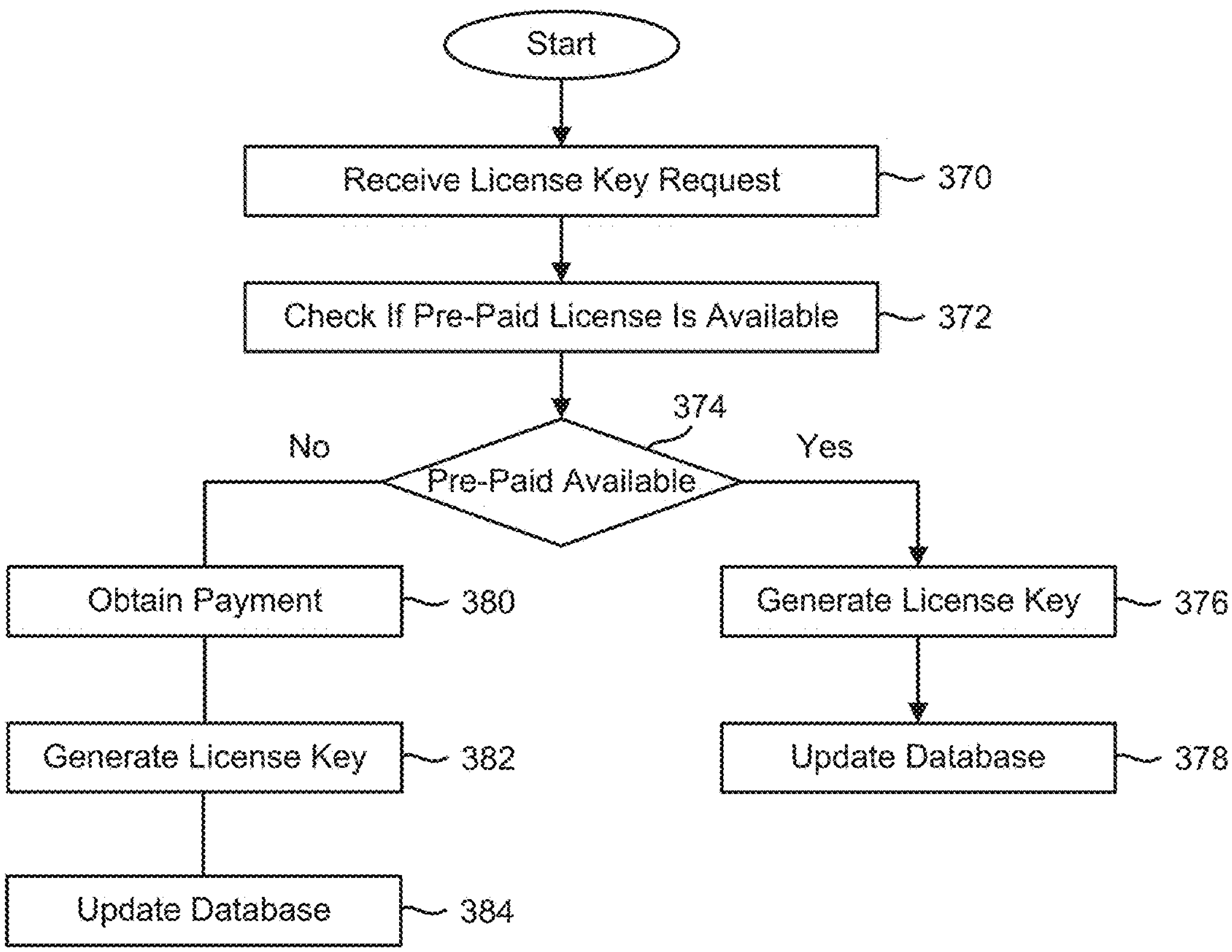

Start
Receive License Key Request
370
Check If Pre-Paid License Is Available
372
374
No
Yes
Pre-Paid Available
Obtain Payment
380
Generate License Key
376
Generate License Key
382
Update Database
378
Update Database
384

FIG. 22A

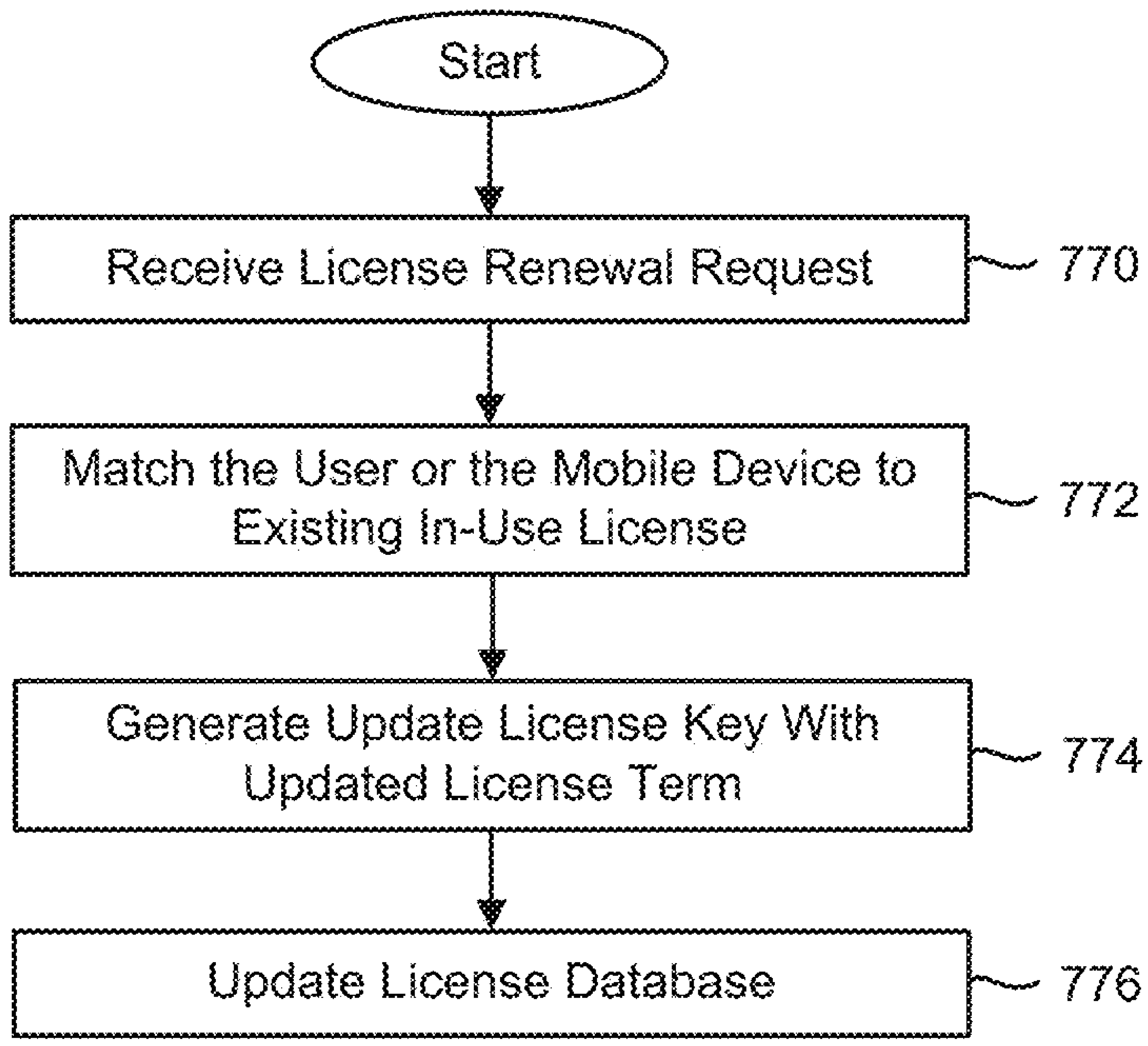

Start
Receive License Renewal Request
770
Match the User or the Mobile Device to Existing In-Use License
772
Generate Update License Key With Updated License Term
774
Update License Database
776

FIG. 22B

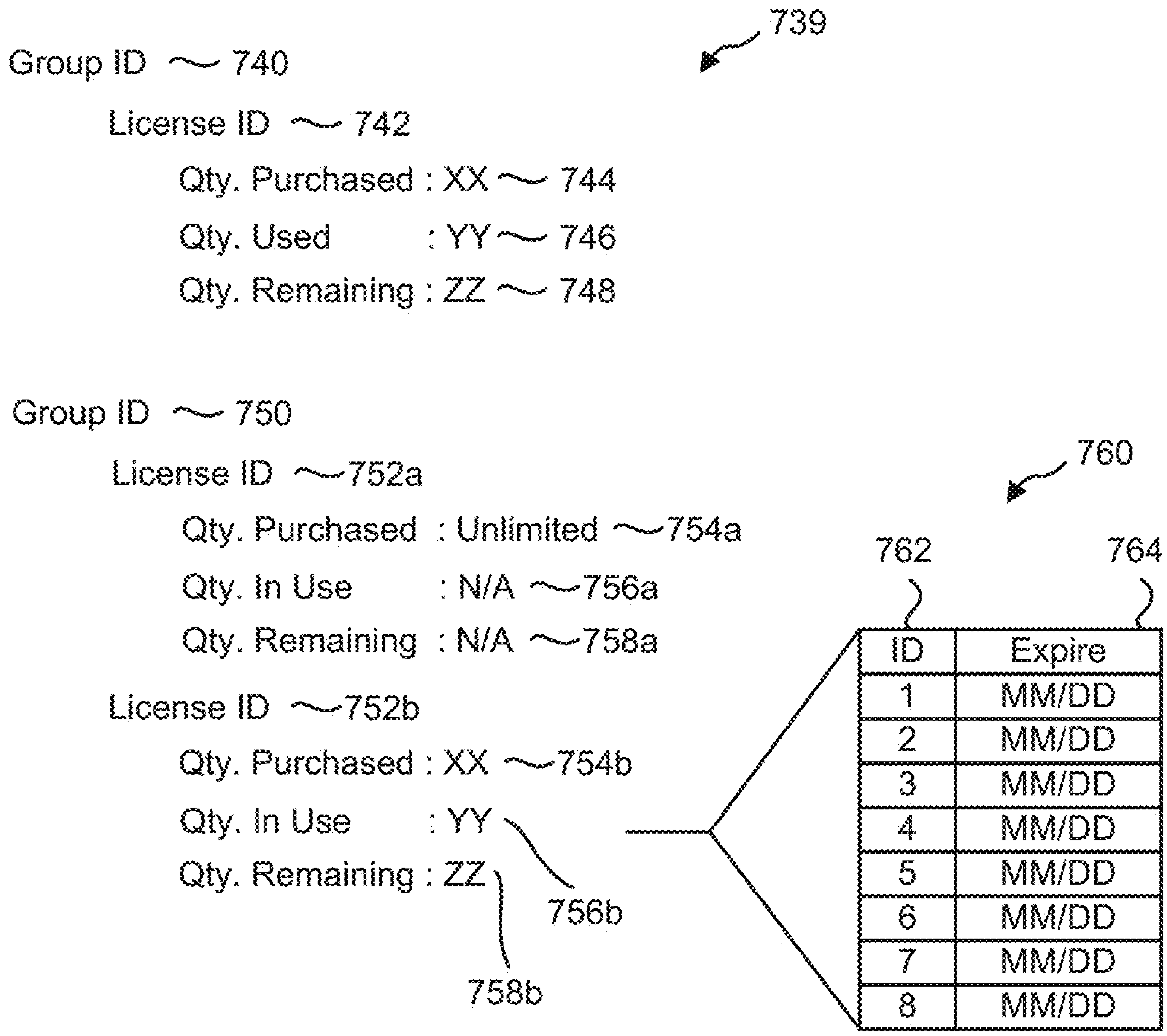
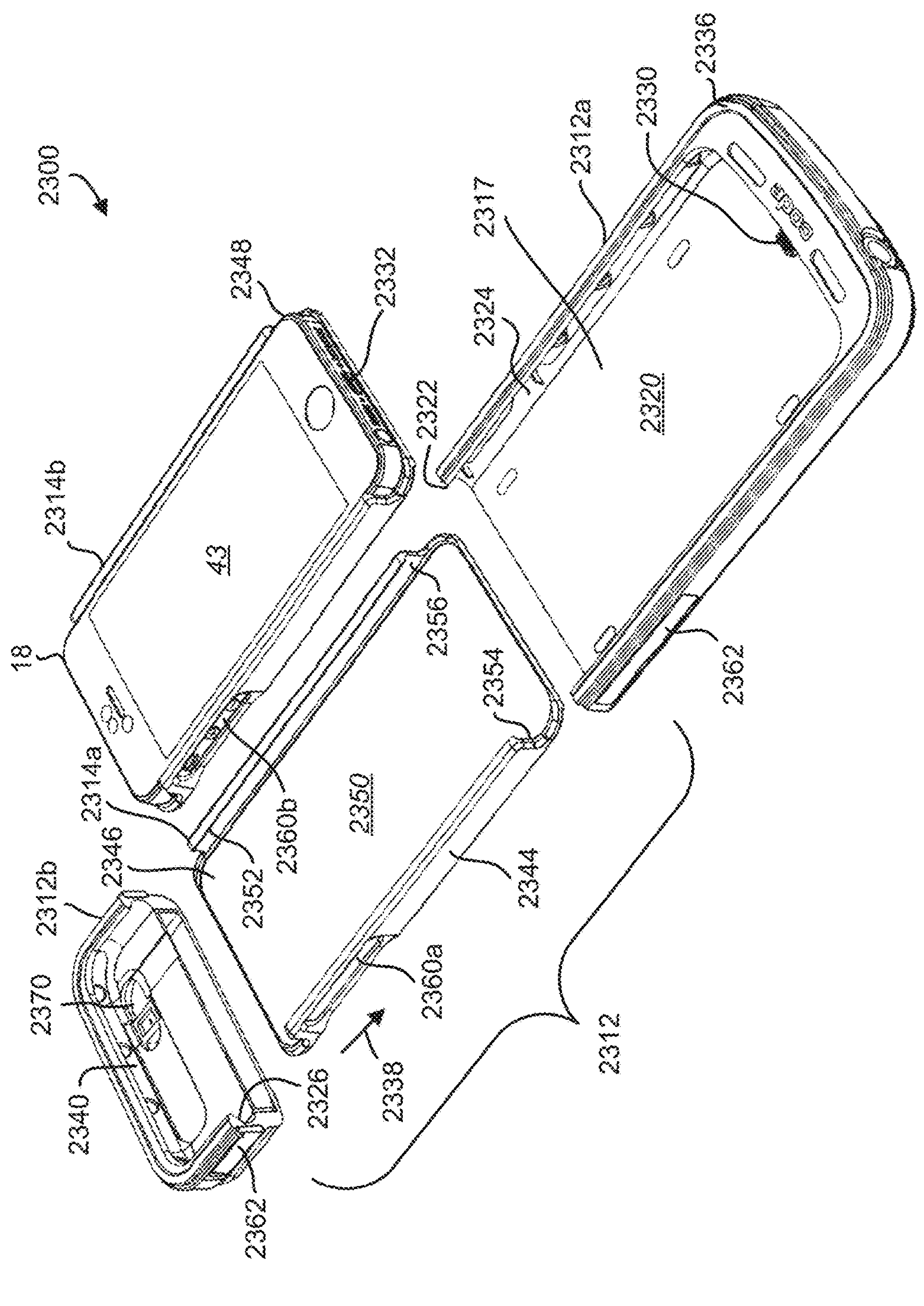

739
Group ID 740
License ID 742
Qty. Purchased : XX 744
Qty. Used : YY 746
Qty. Remaining : ZZ 748
Group ID 750
License ID 752a
Qty. Purchased : Unlimited 754a
Qty. In Use : N/A 756a
Qty. Remaining : N/A 758a
License ID 752b
Qty. Purchased : XX 754b
Qty. In Use : YY
Qty. Remaining : ZZ
756b
758b
760
762
764
ID
Expire
1 MM/DD
2 MM/DD
3 MM/DD
4 MM/DD
5 MM/DD
6 MM/DD
7 MM/DD
8 MM/DD

FIG. 22C



2300
2348
2332
2314b
43
18
2314a
2360b
2346
2352
2312b
2370
2340
2326
2362
2338
2360a
2344
2350
2354
2356
2312
2362
2320
2322
2324
2317
2312a
2330
2336

FIG. 23

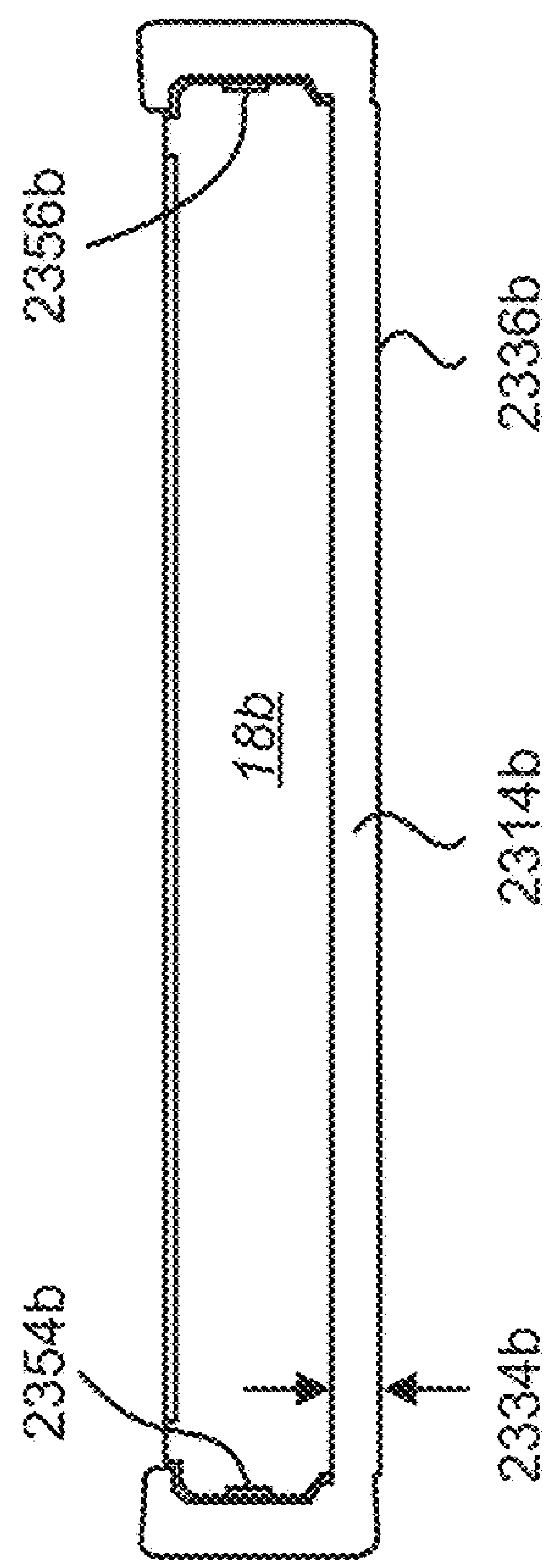


FIG. 24B

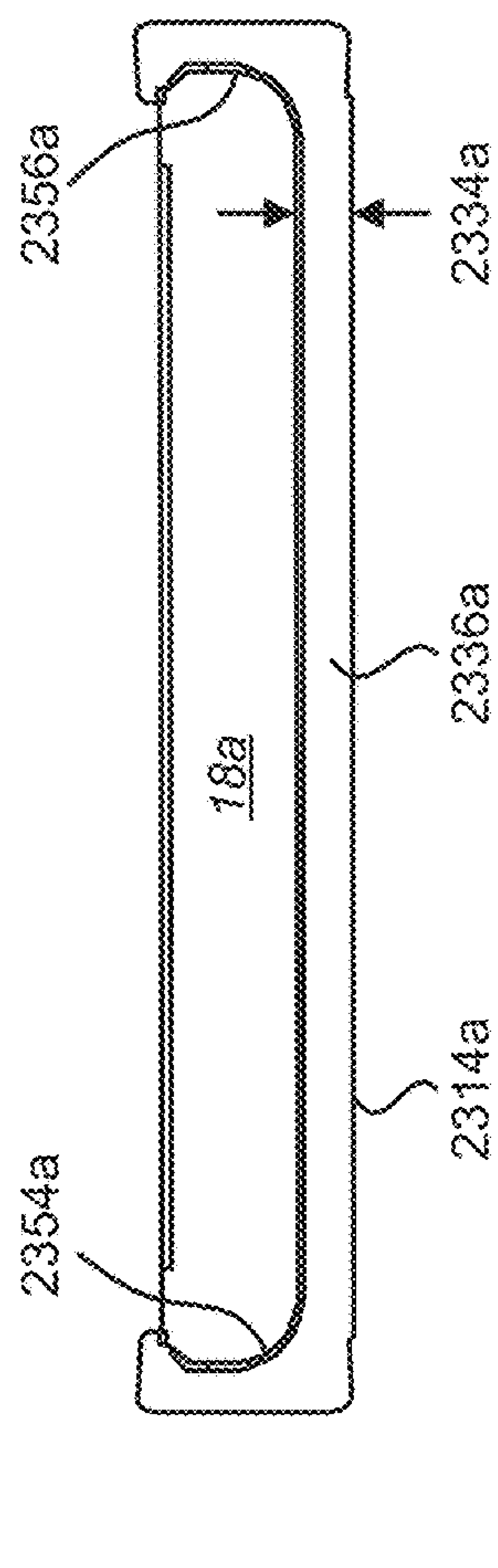


FIG. 24A

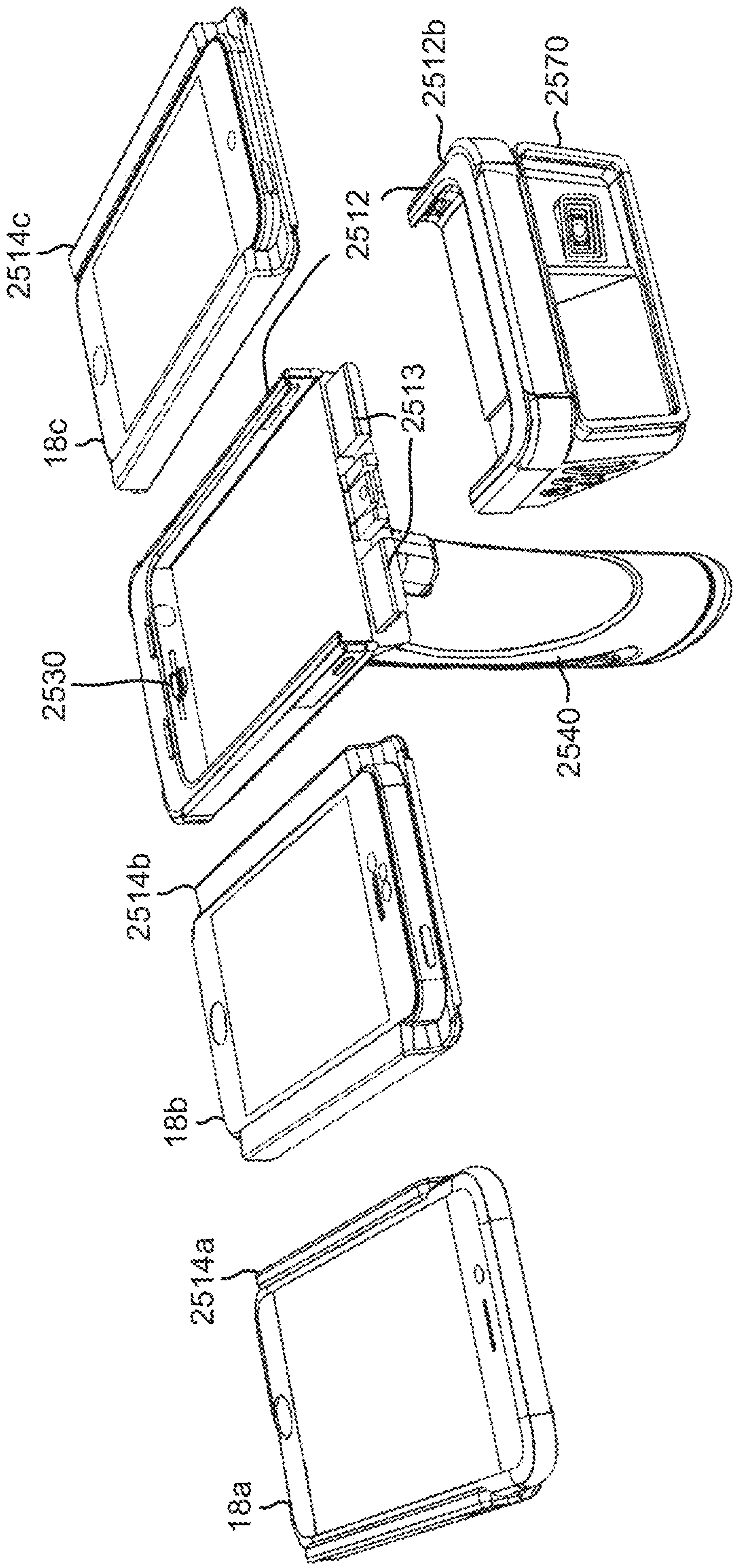


FIG. 25

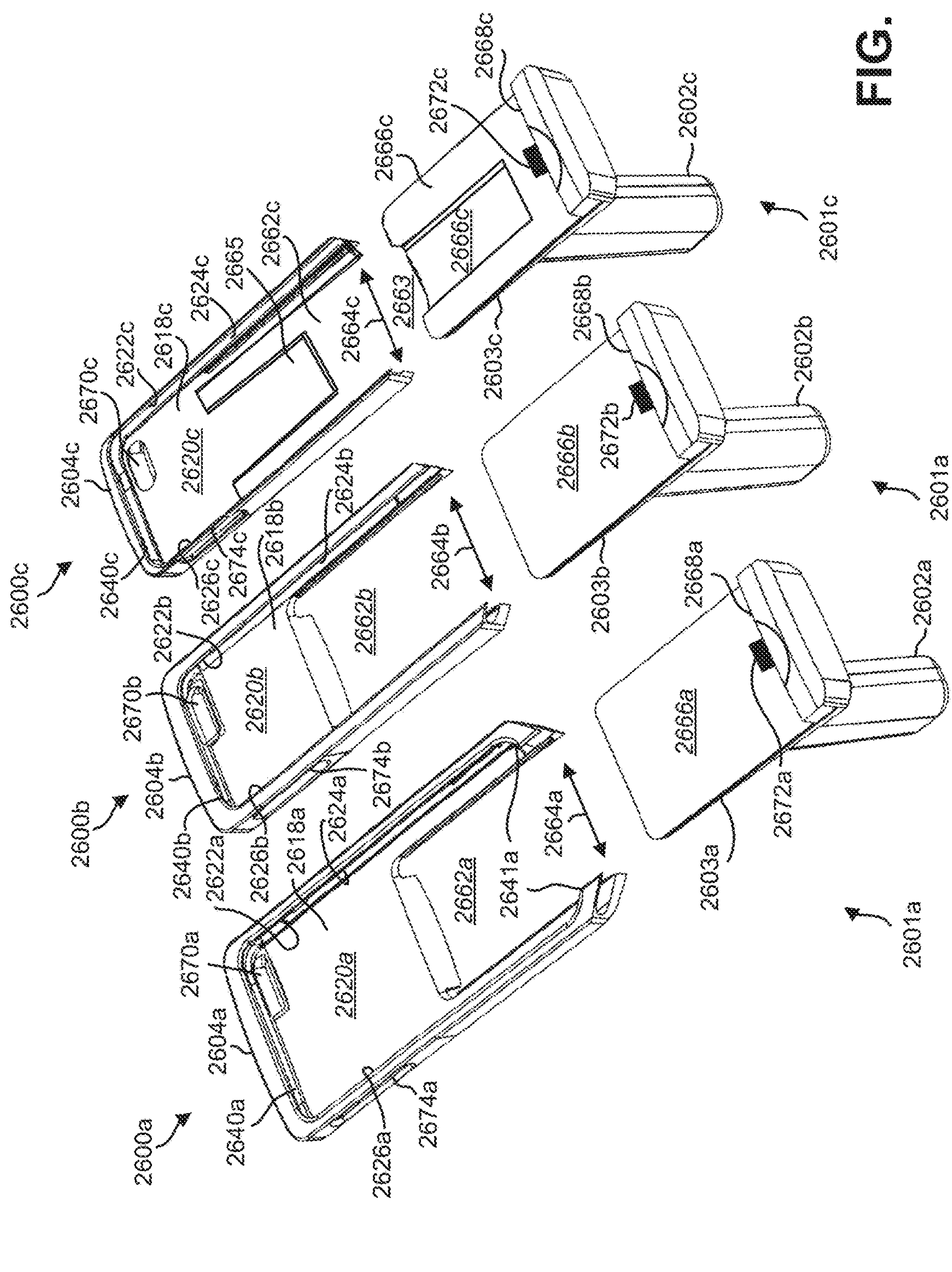

2600a
2600b
2600c
2601a
2601a
2601c
2602a
2602b
2602c
2603a
2603b
2603c
2604a
2604b
2604c
2618a
2618b
2618c
2620a
2620b
2620c
2622a
2622b
2622c
2624a
2624b
2624c
2626a
2626b
2626c
2640a
2640b
2640c
2641a
2662a
2662b
2662c
2663
2664a
2664b
2664c
2665
2666a
2666b
2666c
2666c
2668a
2668b
2668c
2670a
2670b
2670c
2672a
2672b
2672c
2674a
2674b
2674c

FIG. 26

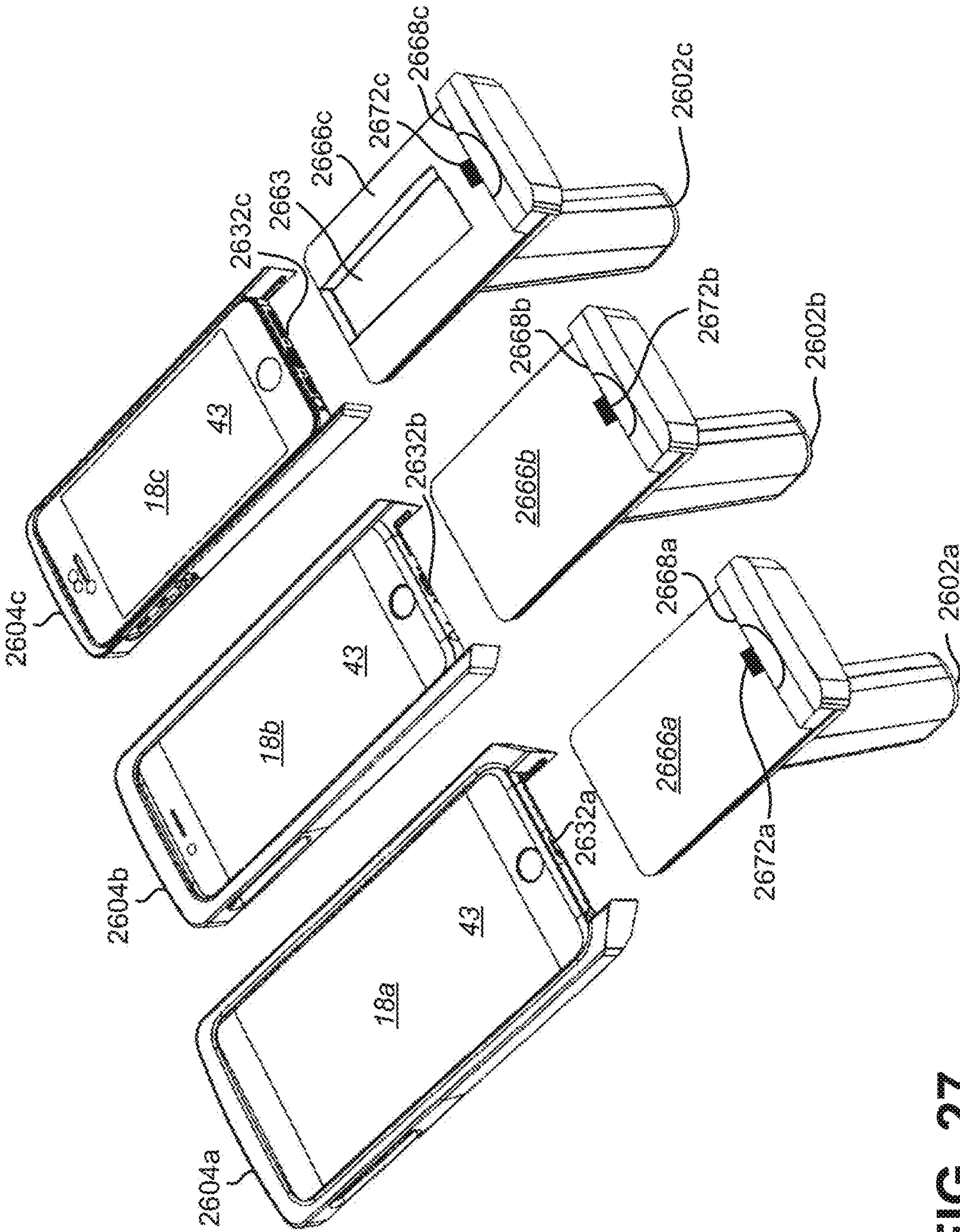

2668c
2602c
2672c
2666c
2663
2632c
2668b
2672b
2602b
2632b
43
18c
2666b
2604c
2668a
2602a
43
18b
2666a
2632a
2672a
2604b
43
18a
2604a

FIG. 27

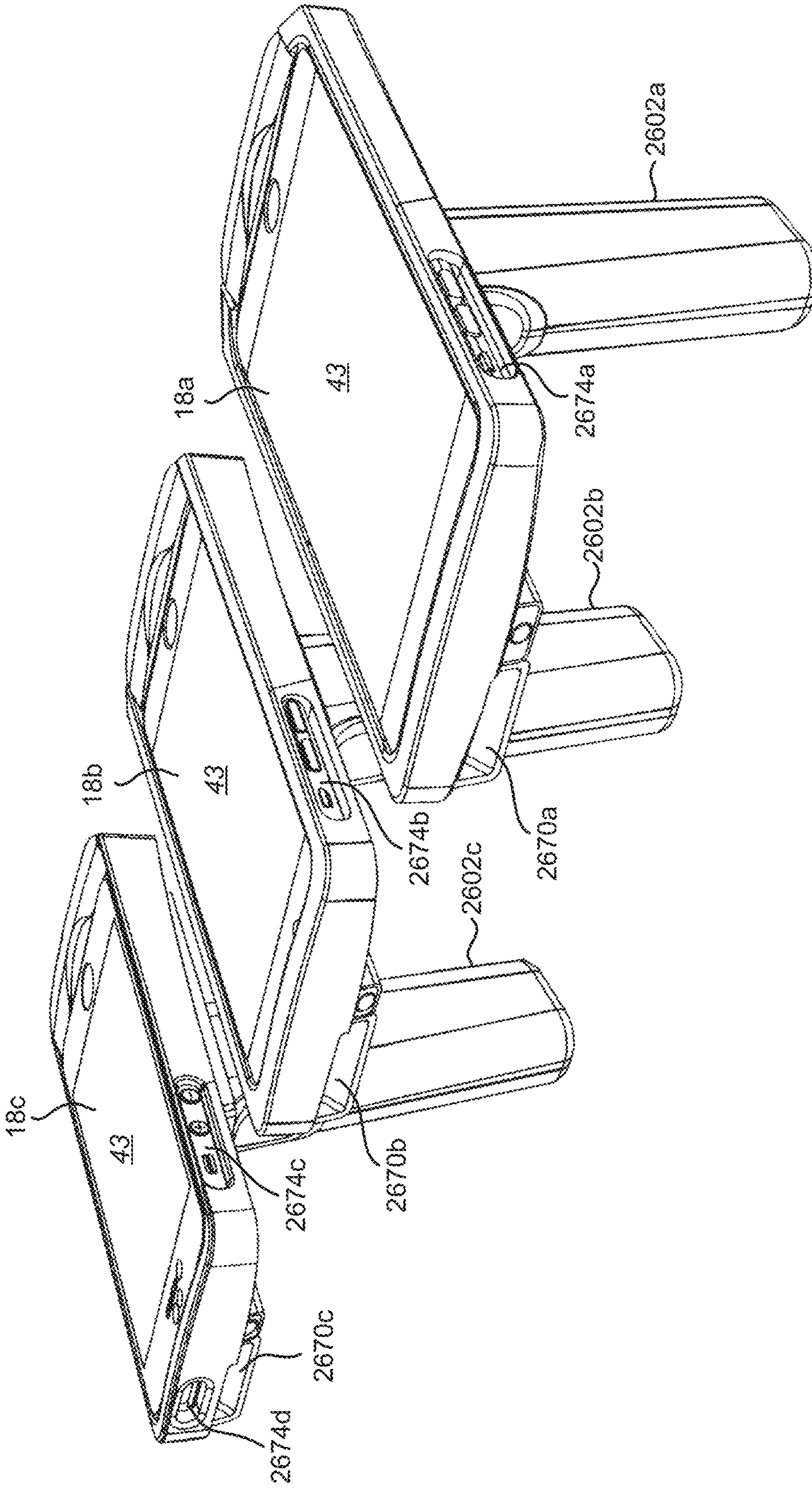

2602a
18a
43
2674a
2602b
18b
43
2674b
2670a
2602c
18c
43
2674c
2670b
2670c
2674d

FIG. 28

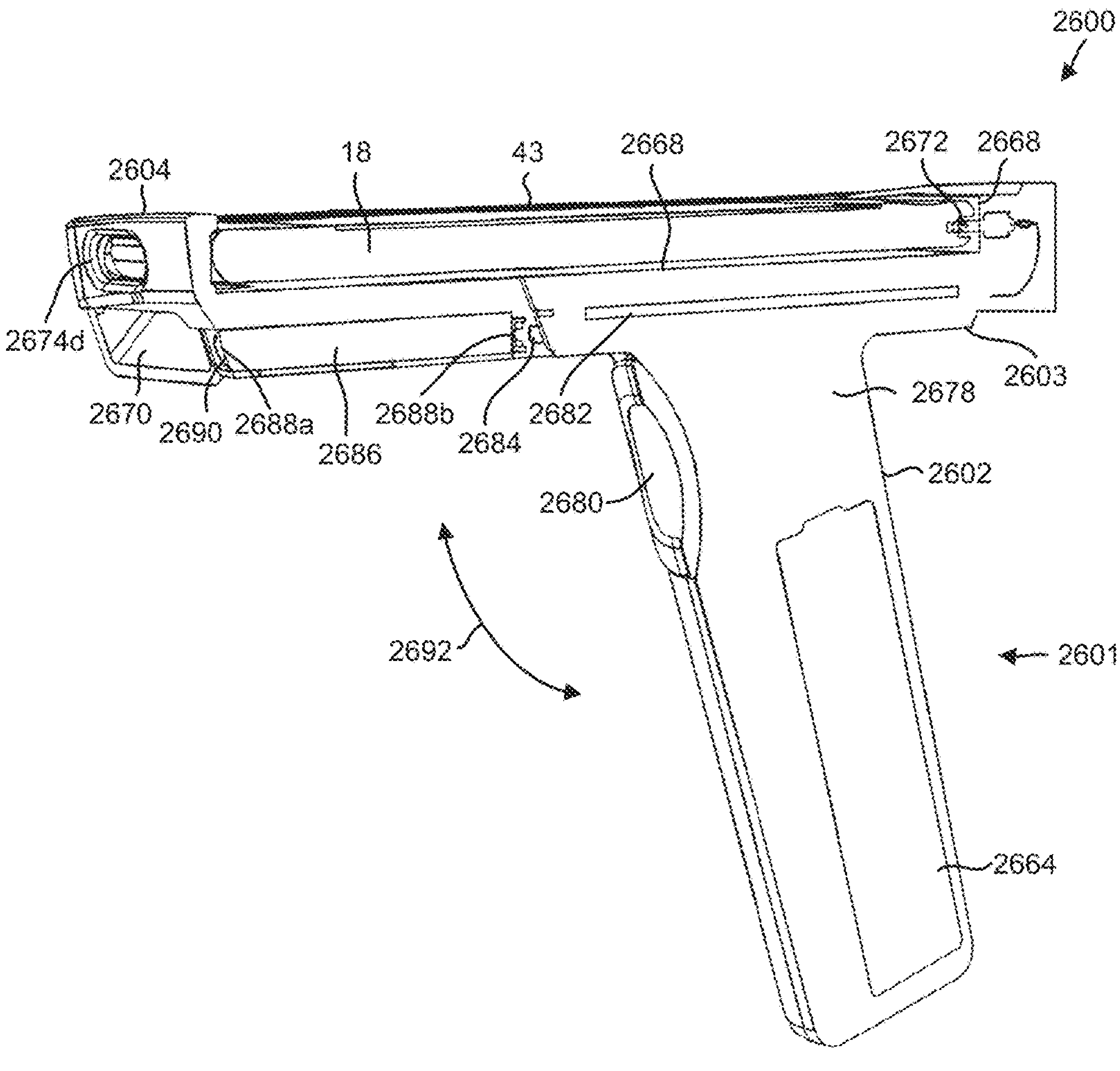

2600
2604
18
43
2668
2672
2668
2674d
2603
2670
2690
2688a
2686
2688b
2684
2682
2678
2602
2680
2692
2601
2664

FIG. 29

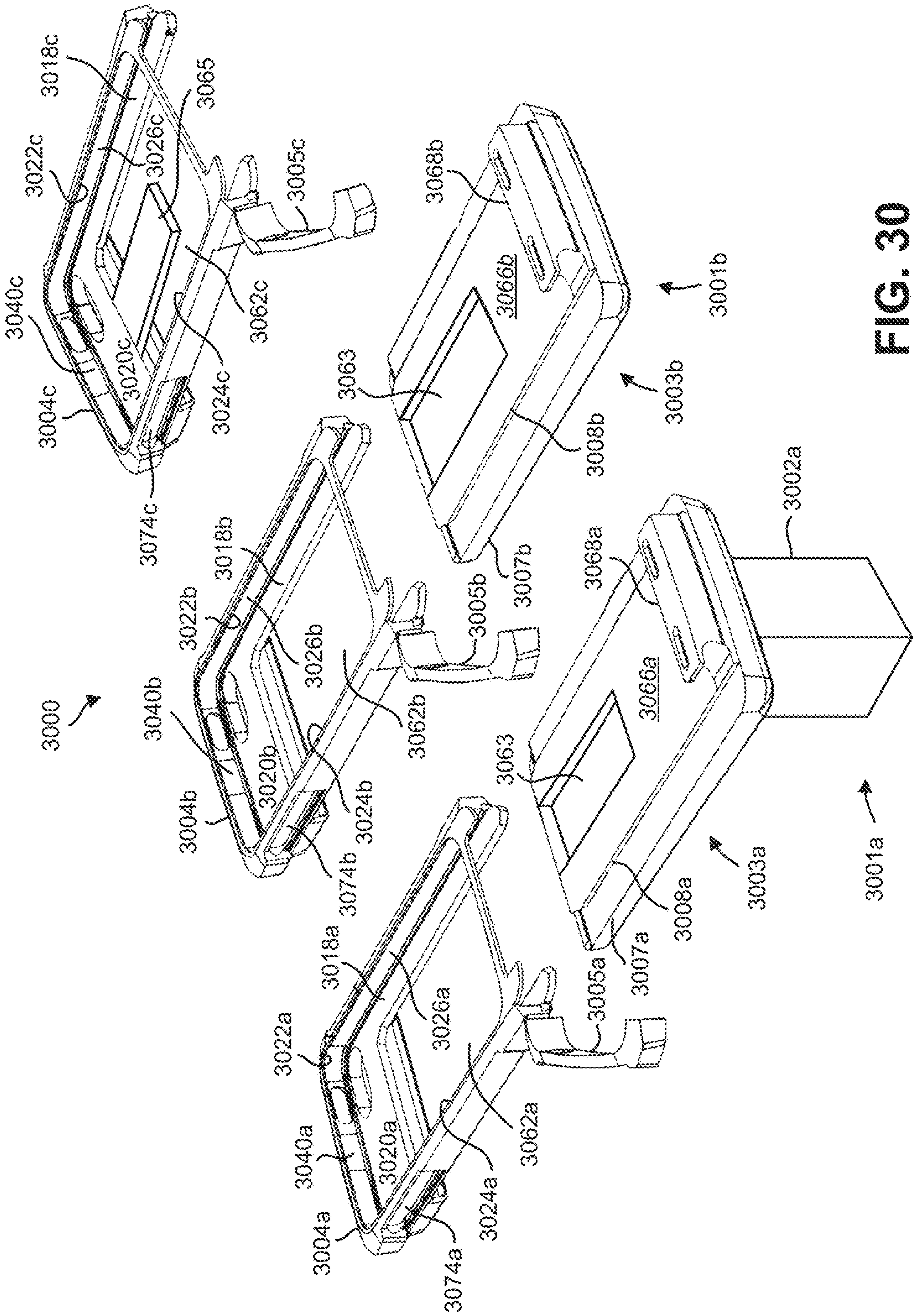

3000
3018c
3022c
3026c
3065
3005c
3040c
3020c
3062c
3024c
3004c
3074c
3068b
3066b
3001b
3063
3003b
3008b
3007b
3018b
3022b
3026b
3005b
3040b
3020b
3062b
3024b
3004b
3074b
3002a
3068a
3066a
3063
3003a
3008a
3007a
3001a
3018a
3022a
3026a
3005a
3040a
3020a
3062a
3024a
3004a
3074a

FIG. 30

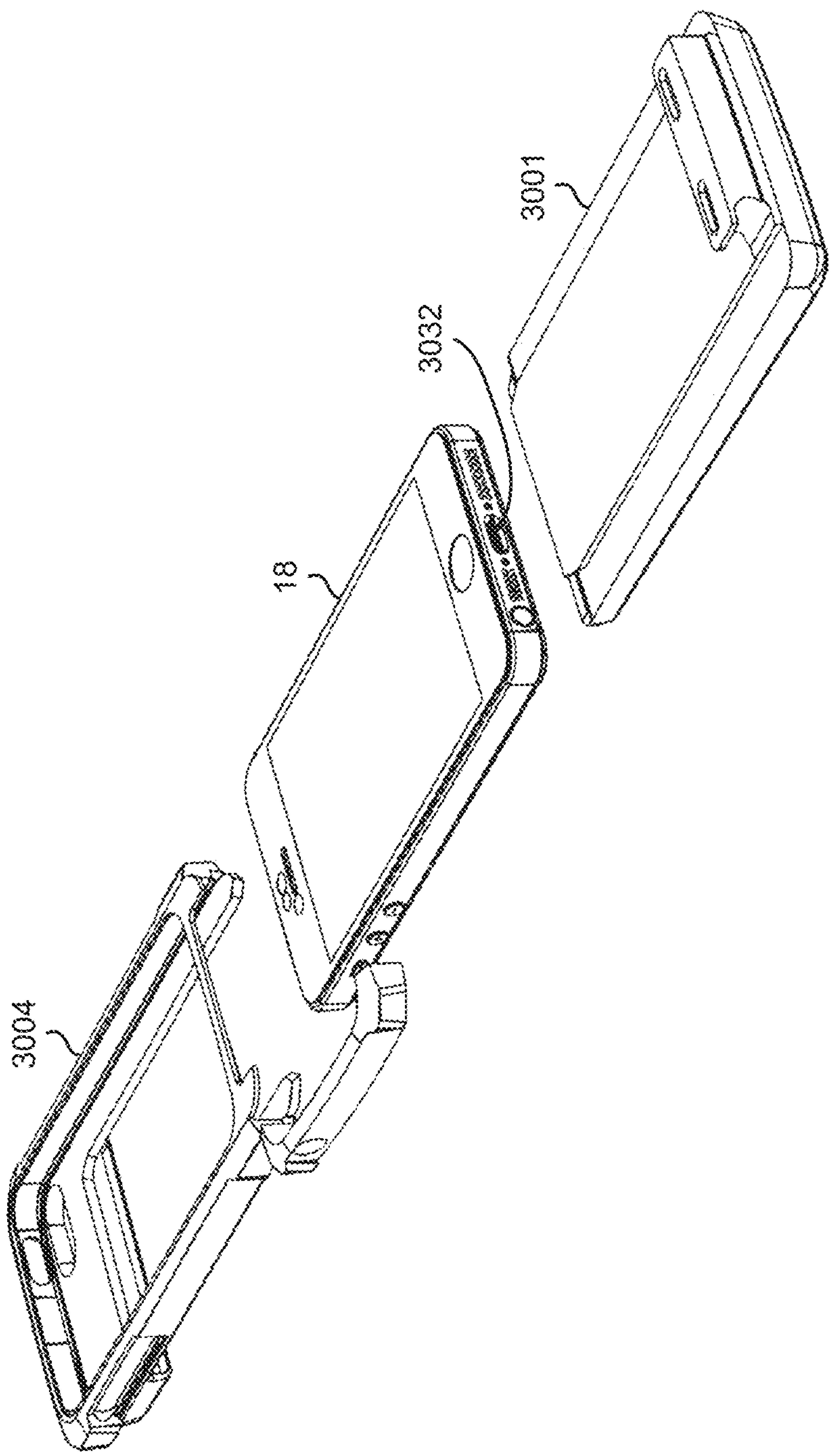


FIG. 31

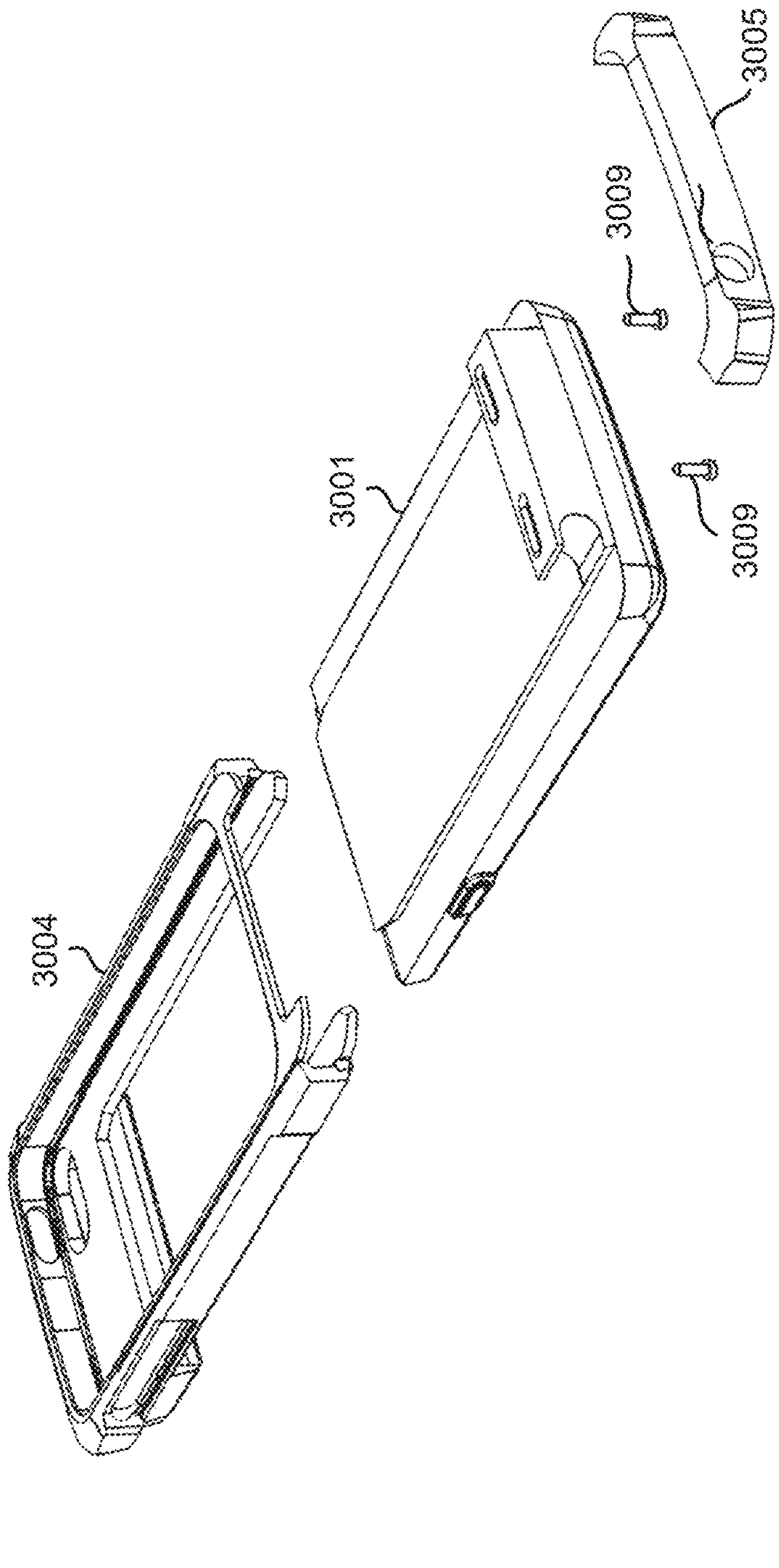


FIG. 32

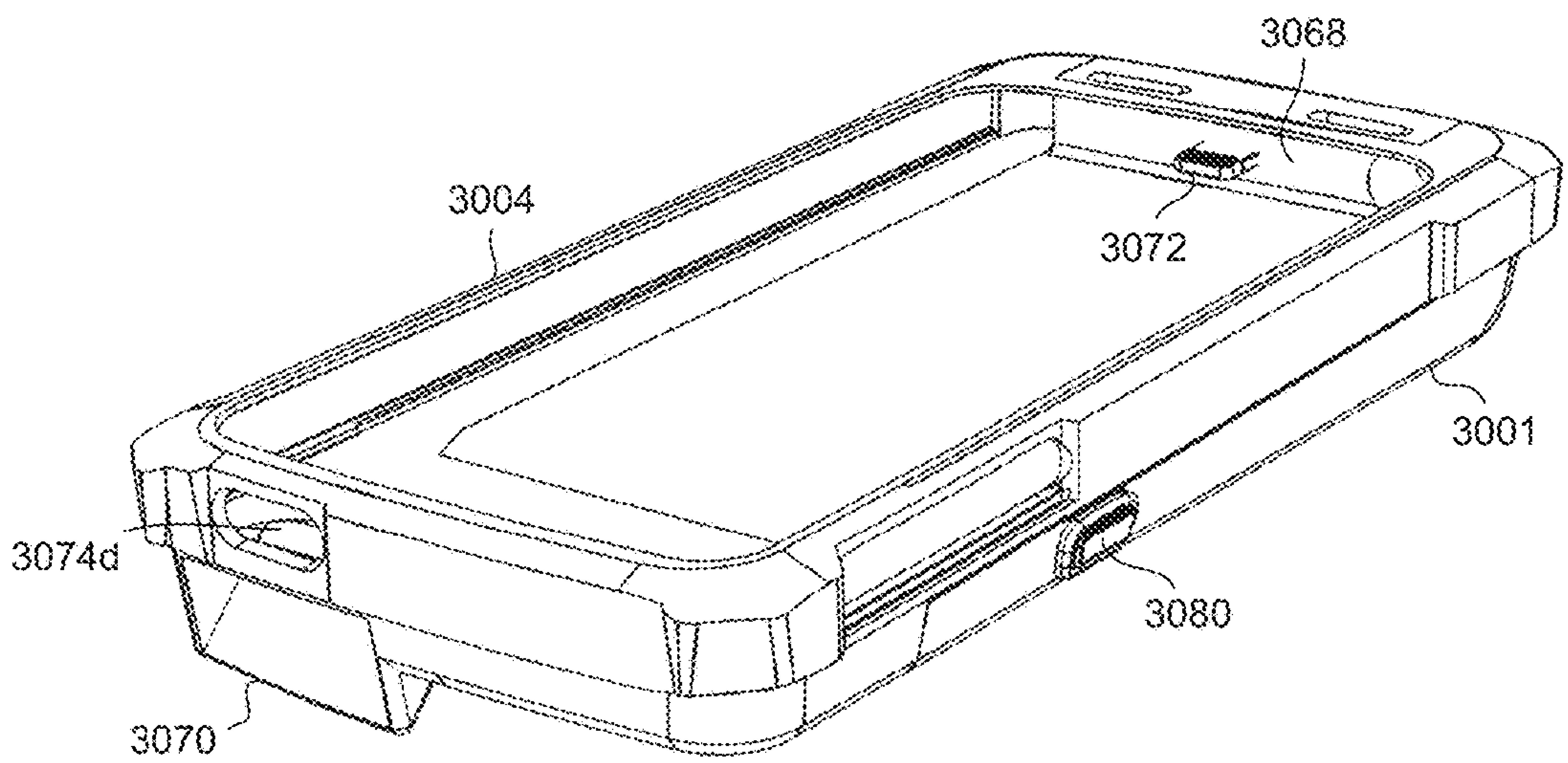


FIG. 33

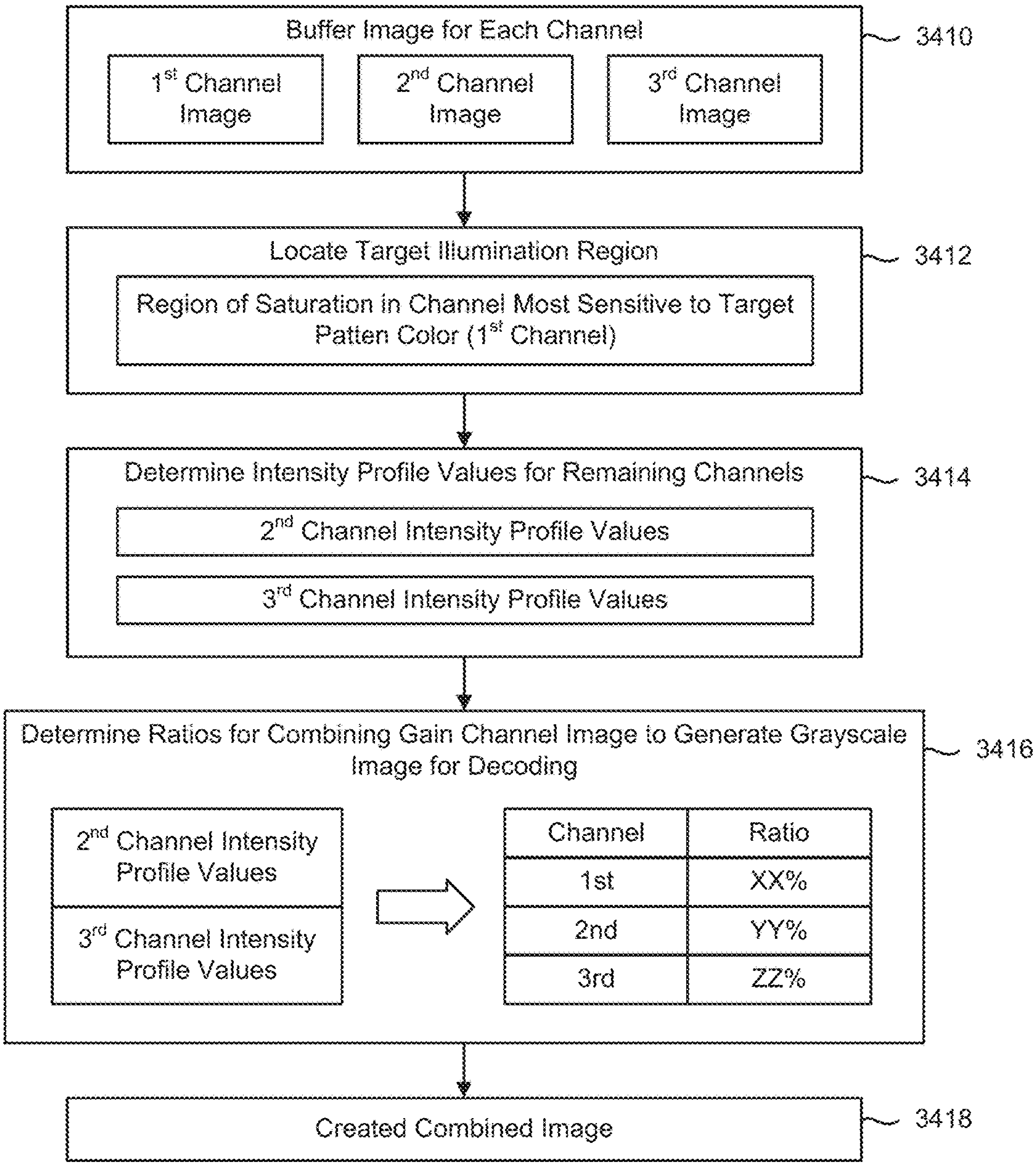

Buffer Image for Each Channel
1st Channel Image
2nd Channel Image
3rd Channel Image
3410
Locate Target Illumination Region
Region of Saturation in Channel Most Sensitive to Target Patten Color (1st Channel)
3412
Determine Intensity Profile Values for Remaining Channels
2nd Channel Intensity Profile Values
3rd Channel Intensity Profile Values
3414
Determine Ratios for Combining Gain Channel Image to Generate Grayscale Image for Decoding
2nd Channel Intensity Profile Values
3rd Channel Intensity Profile Values
Channel
Ratio
1st
XX%
2nd
YY%
3rd
ZZ%
3416
Created Combined Image
3418

FIG. 34

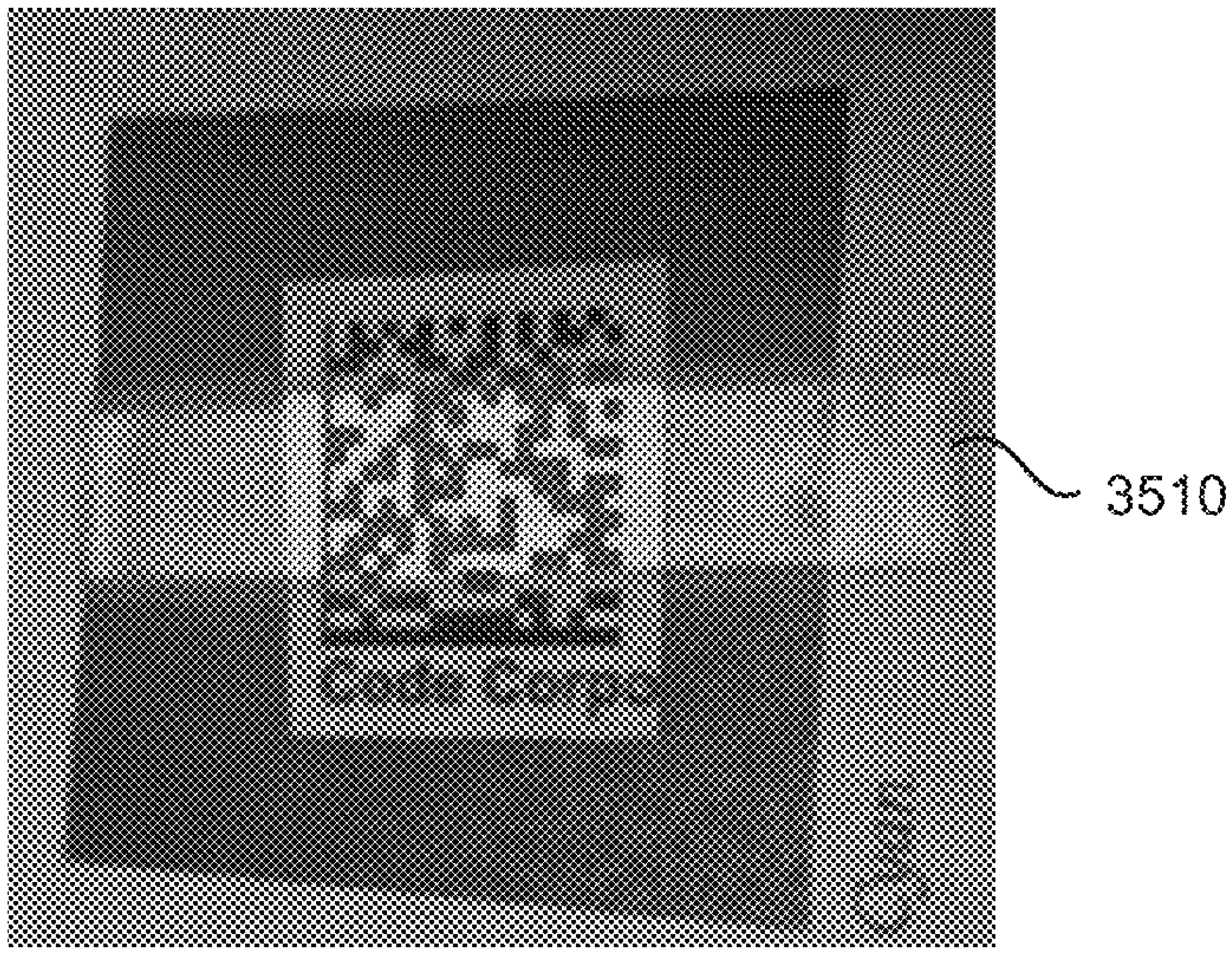


FIG. 35A

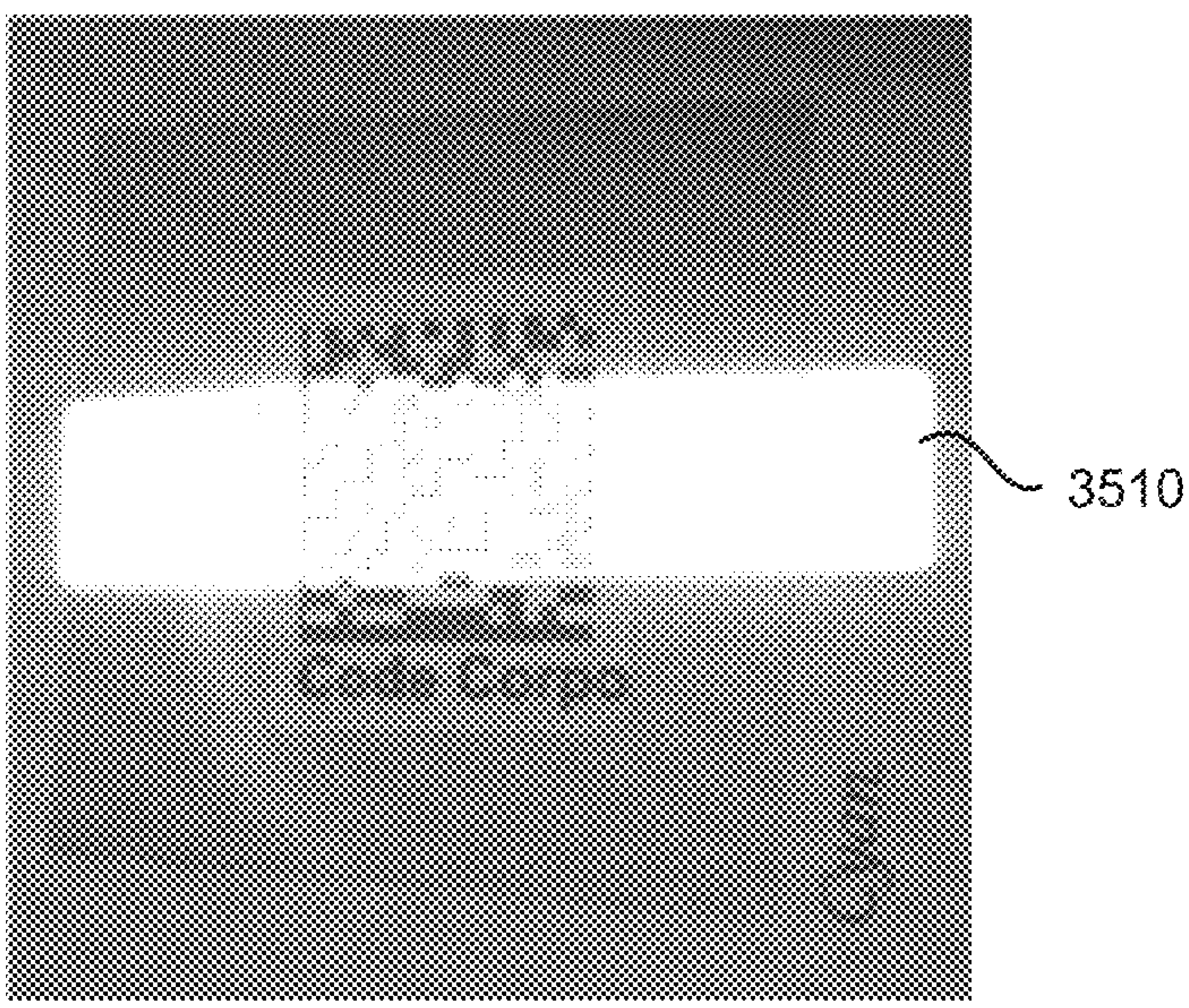


FIG. 35B

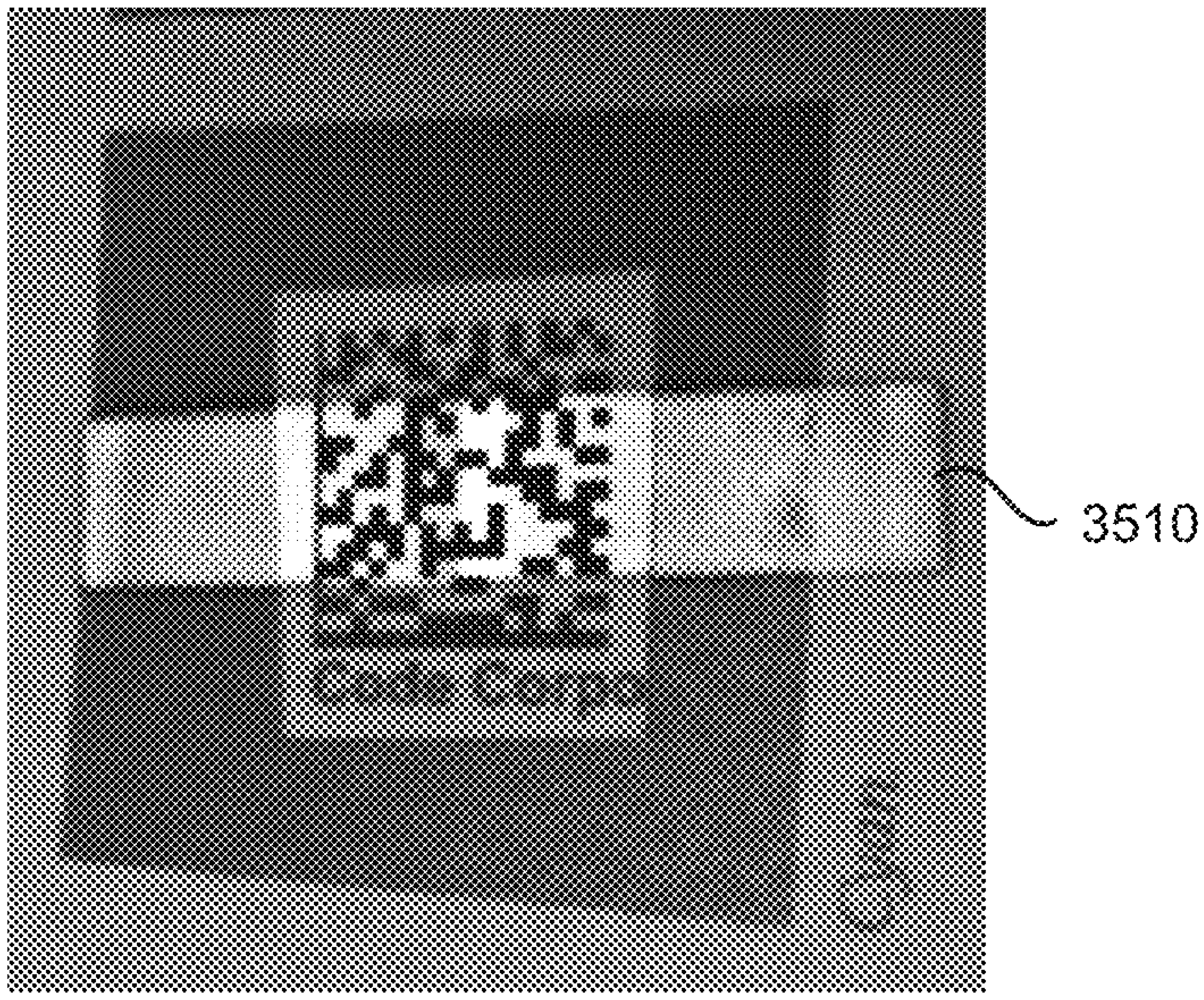


FIG. 35C

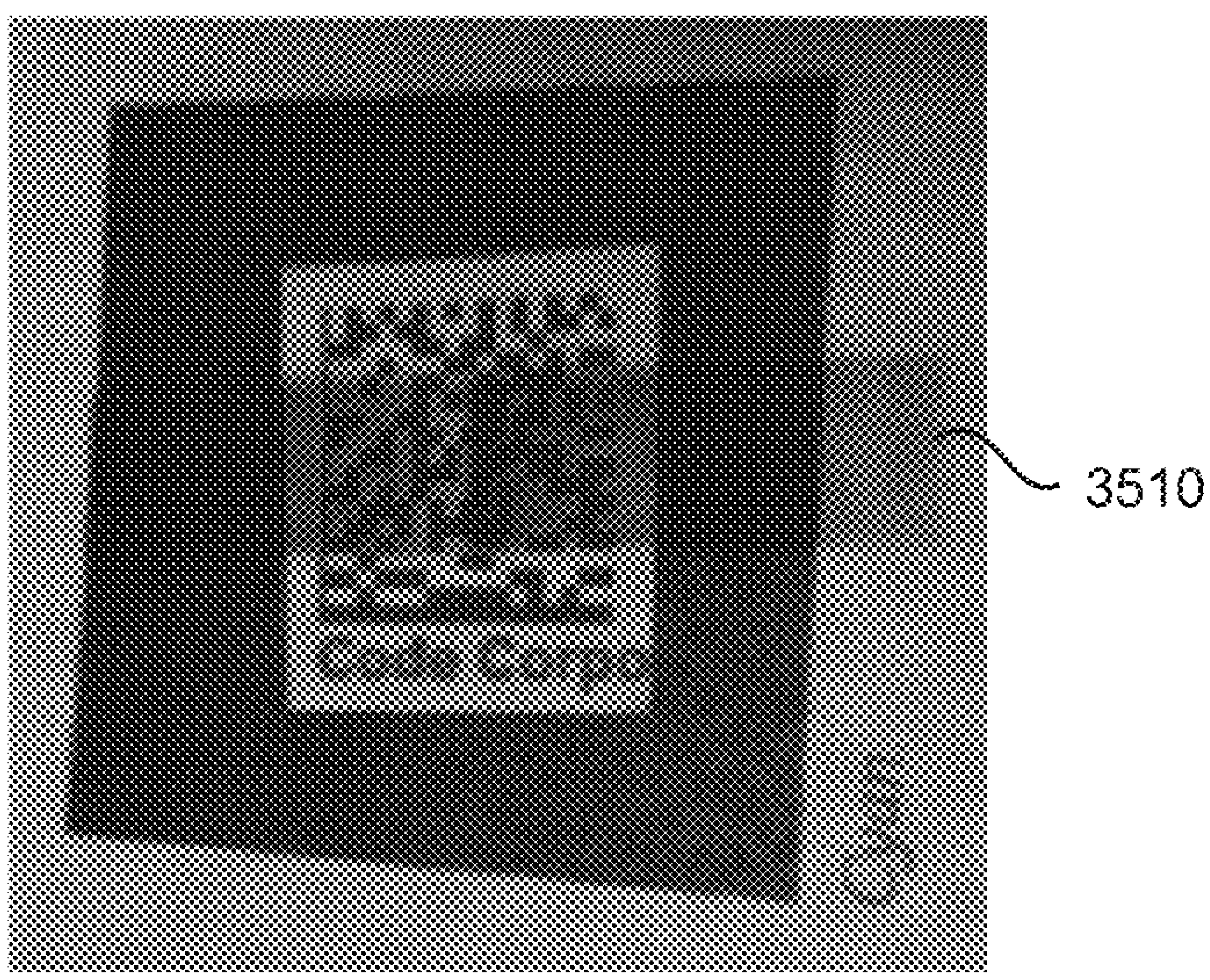
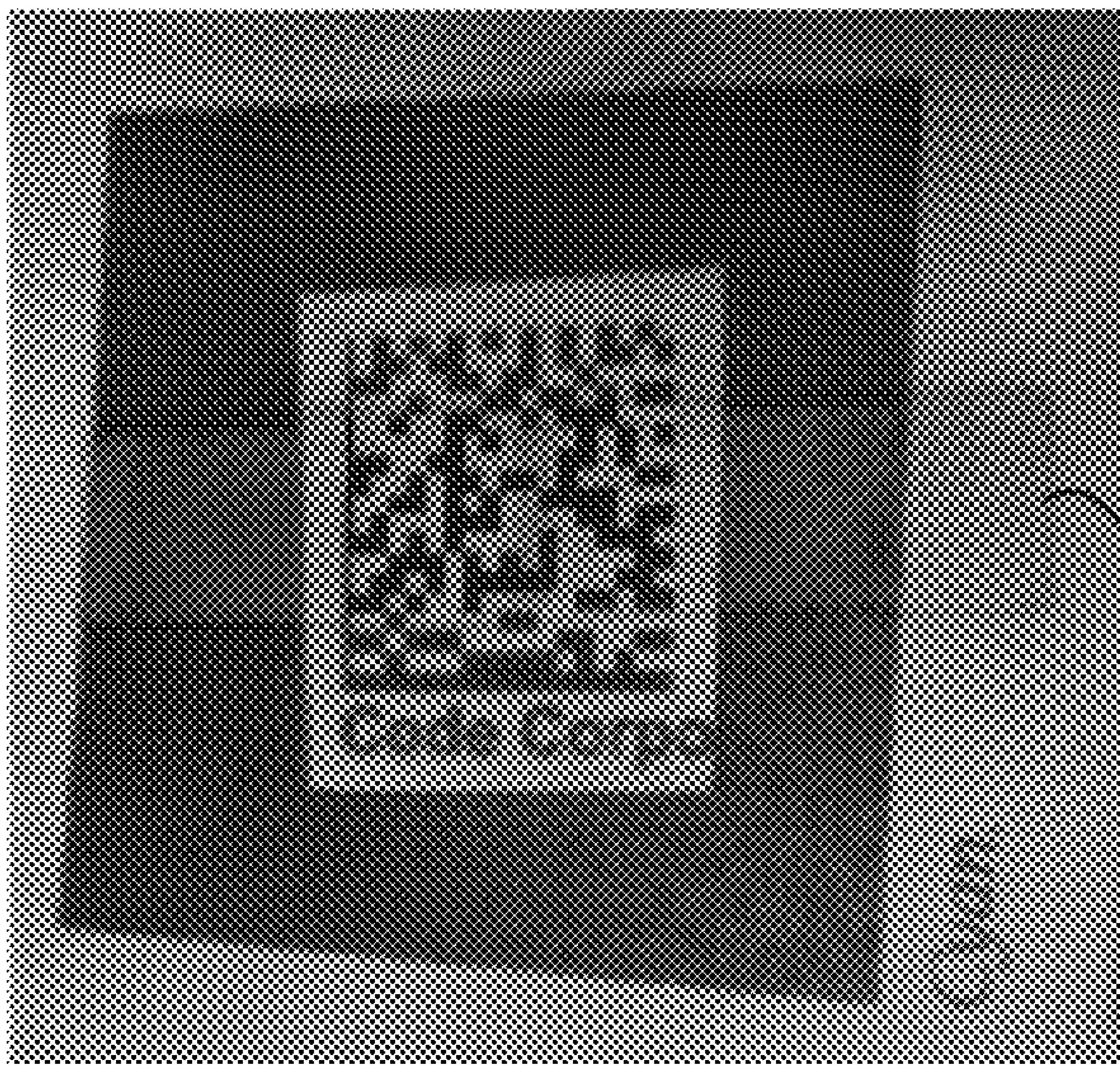
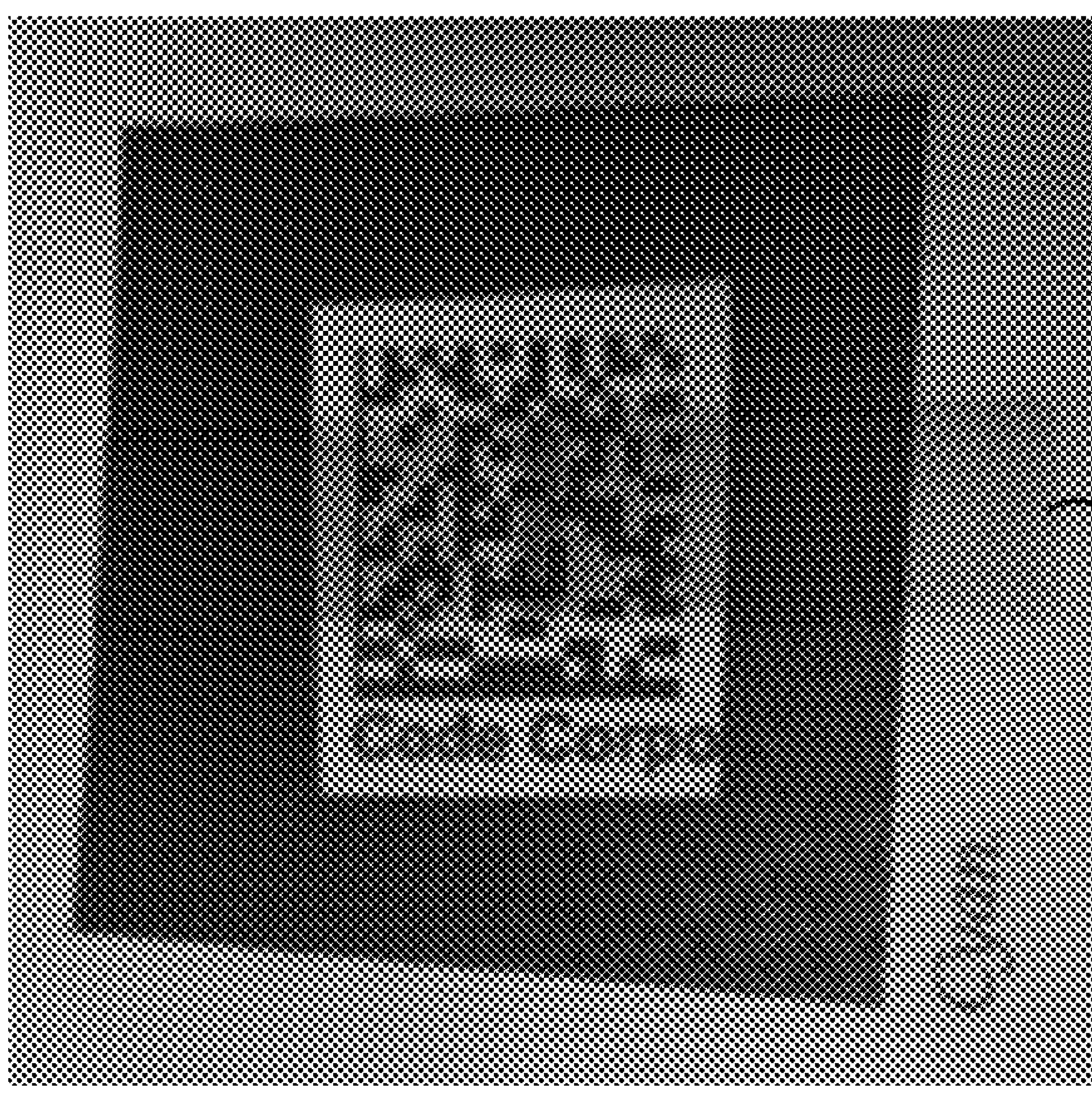


FIG. 35D



3510

FIG. 36A



3510

FIG. 36B

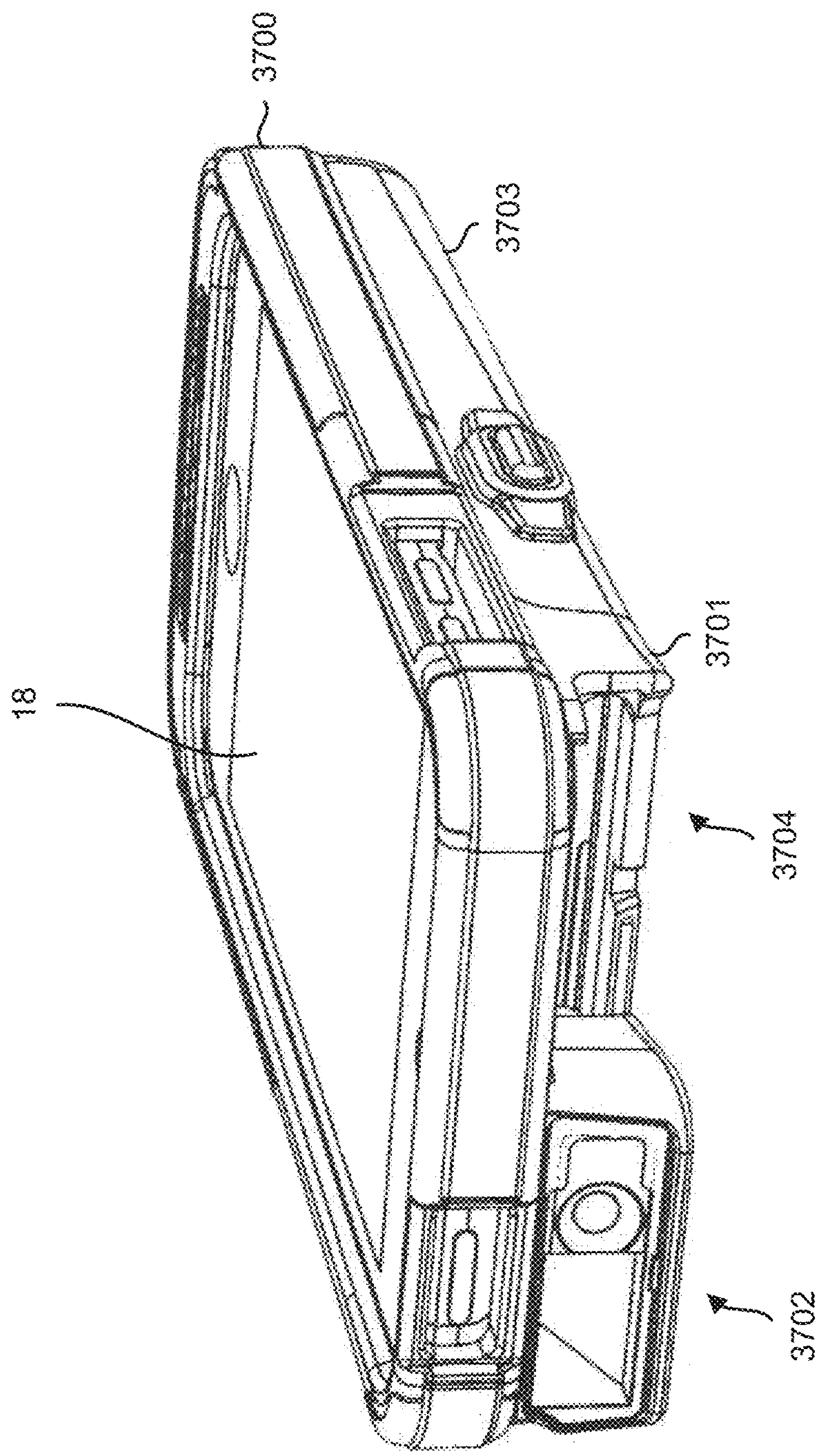


FIG. 37A

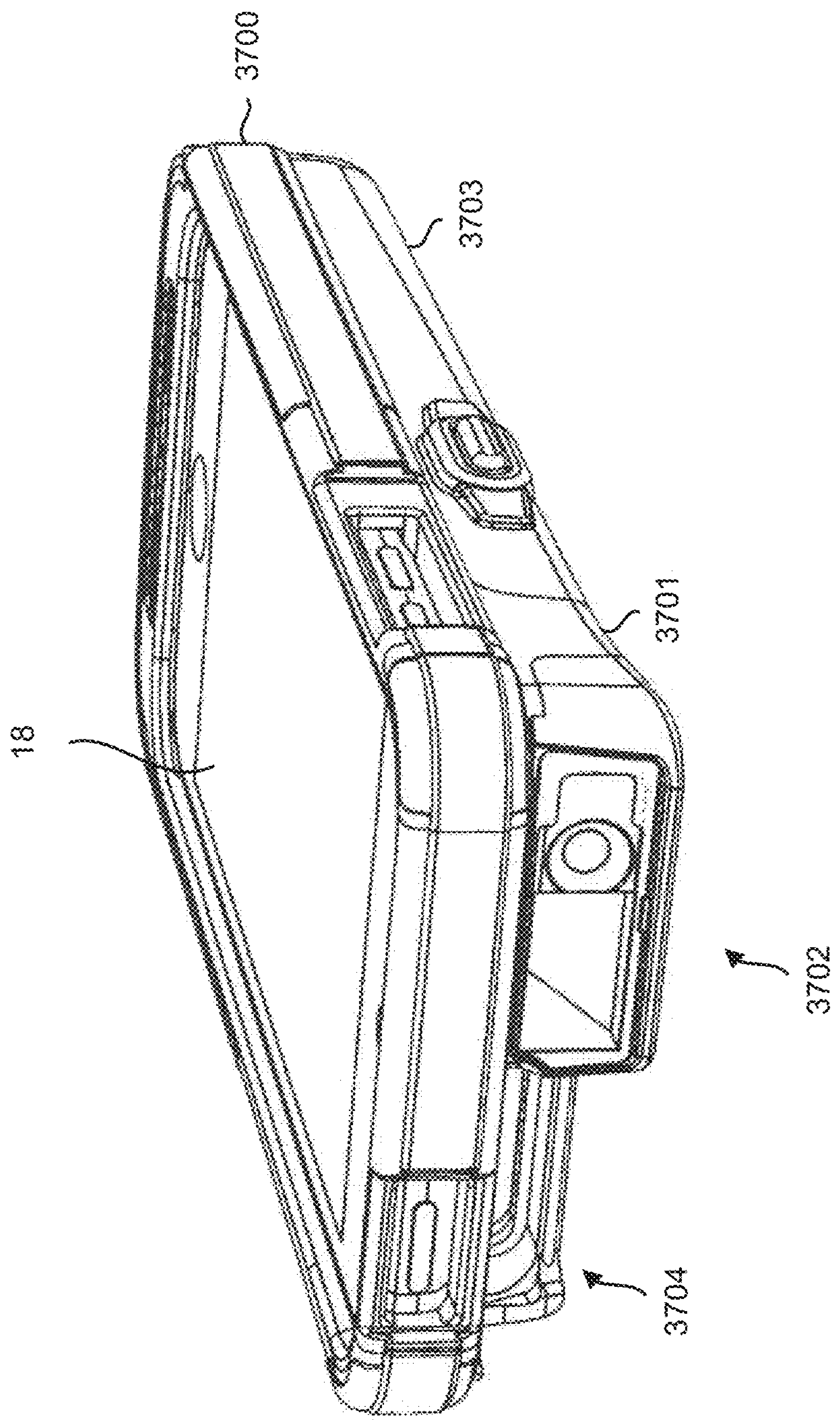


FIG. 37B

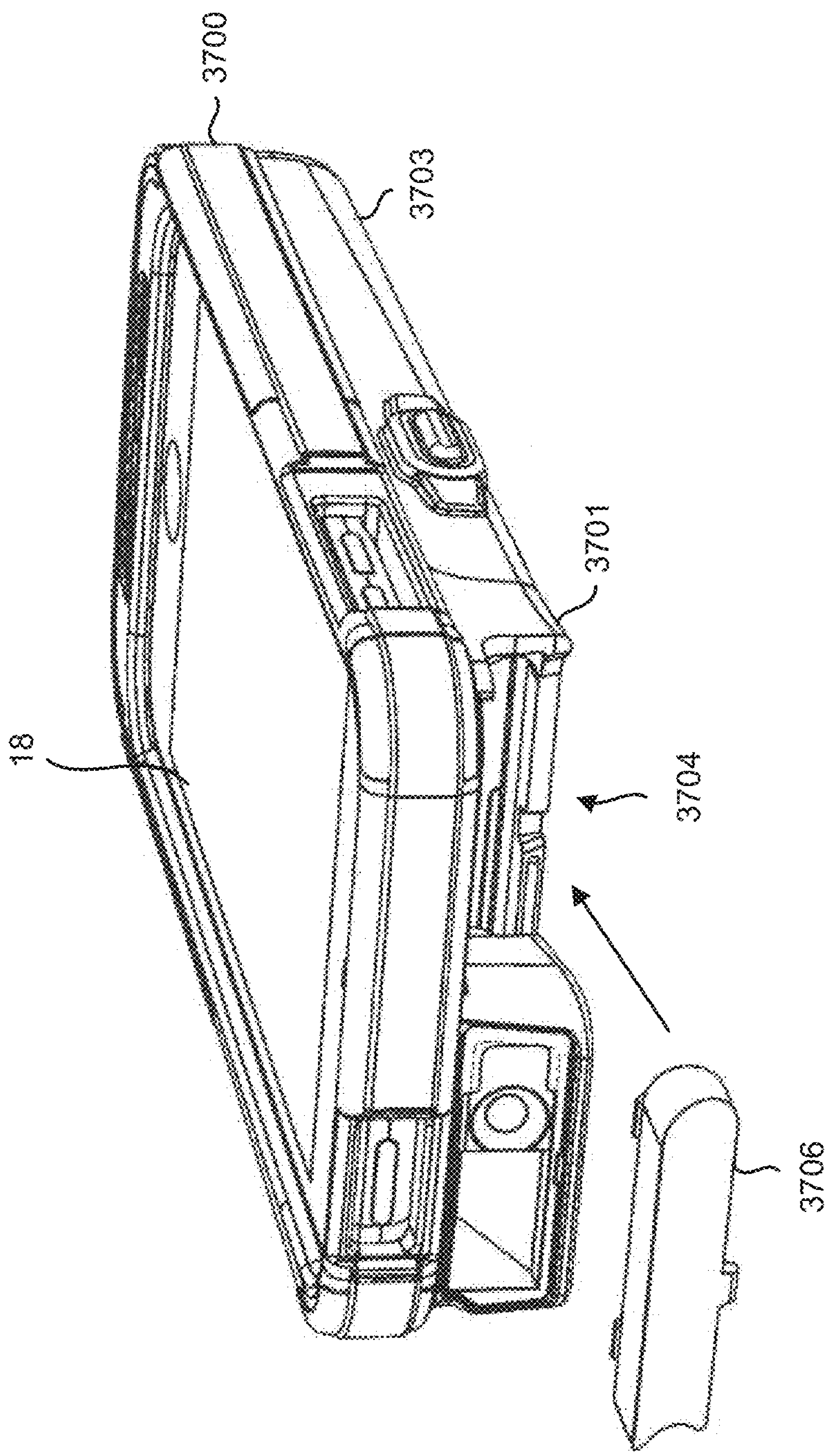


FIG. 37C

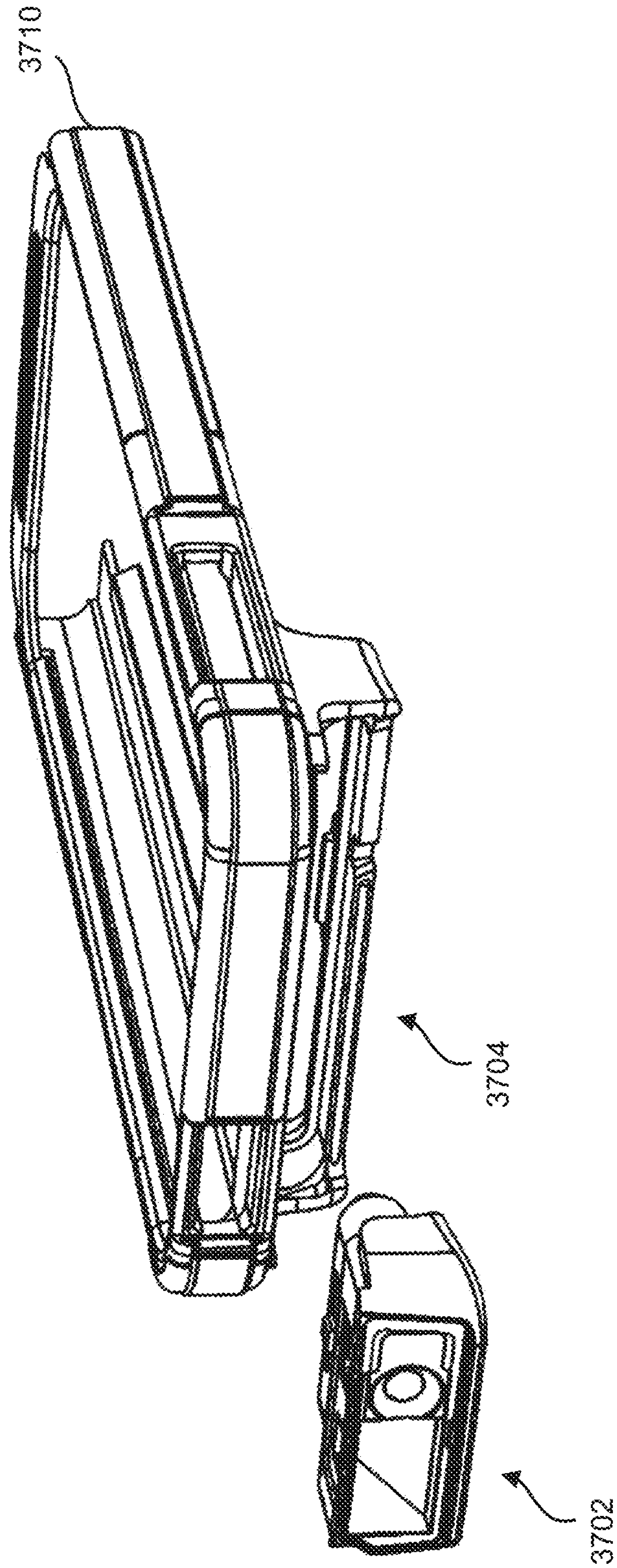


FIG. 38

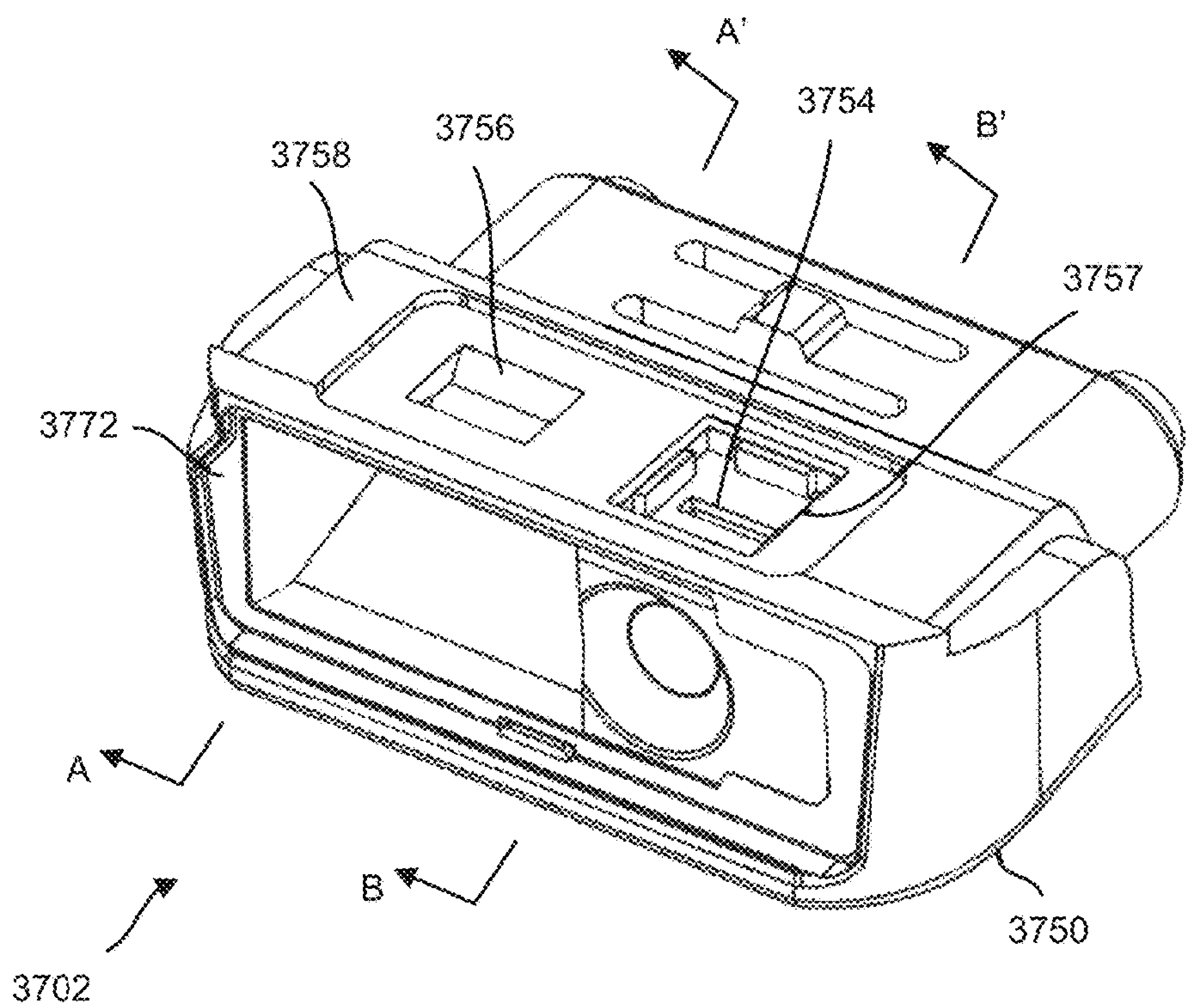


FIG. 39A

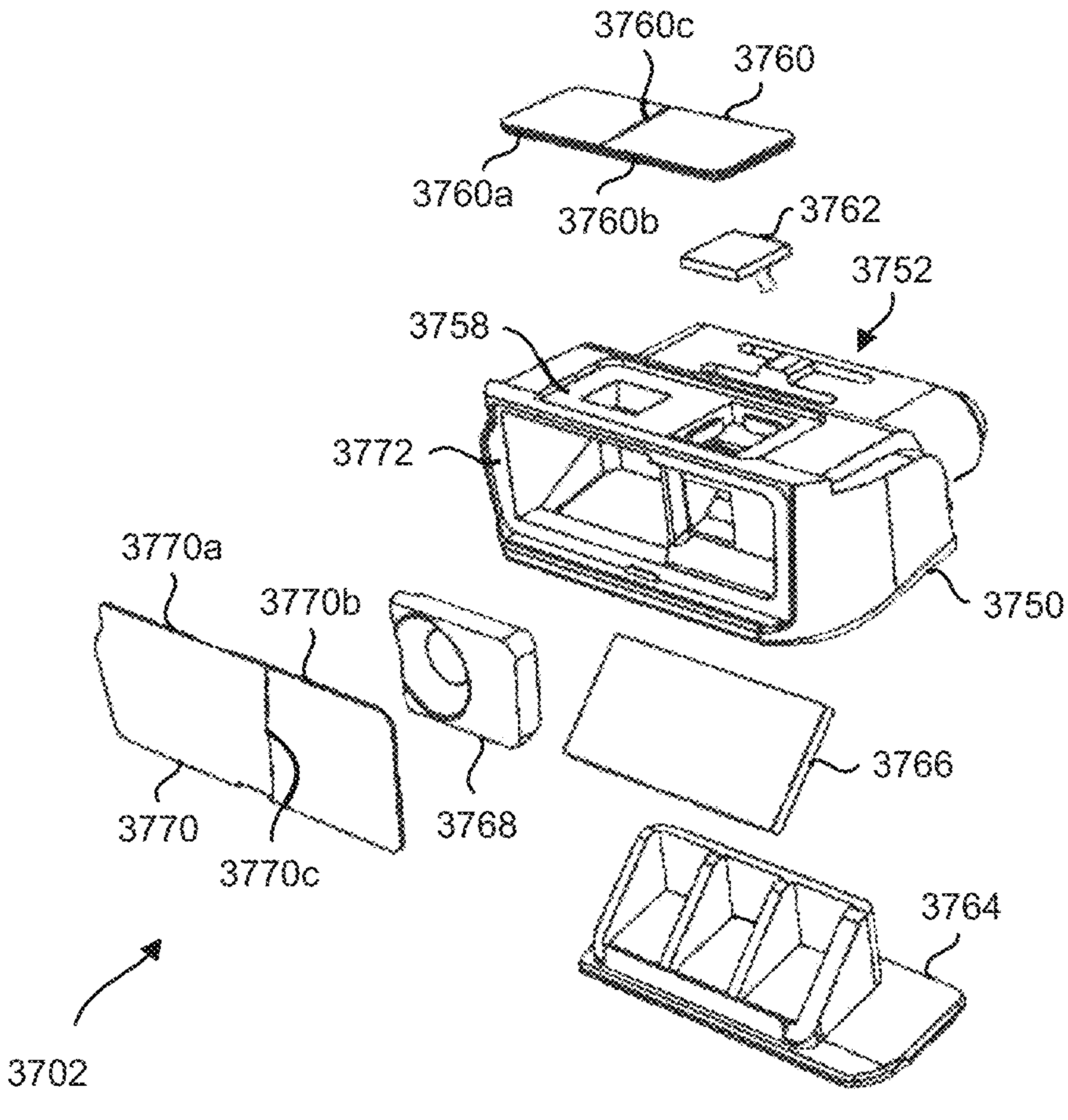

3760c
3760
3760a
3760b
3762
3752
3758
3772
3770a
3770b
3750
3766
3770
3768
3770c
3764
3702

FIG. 39B

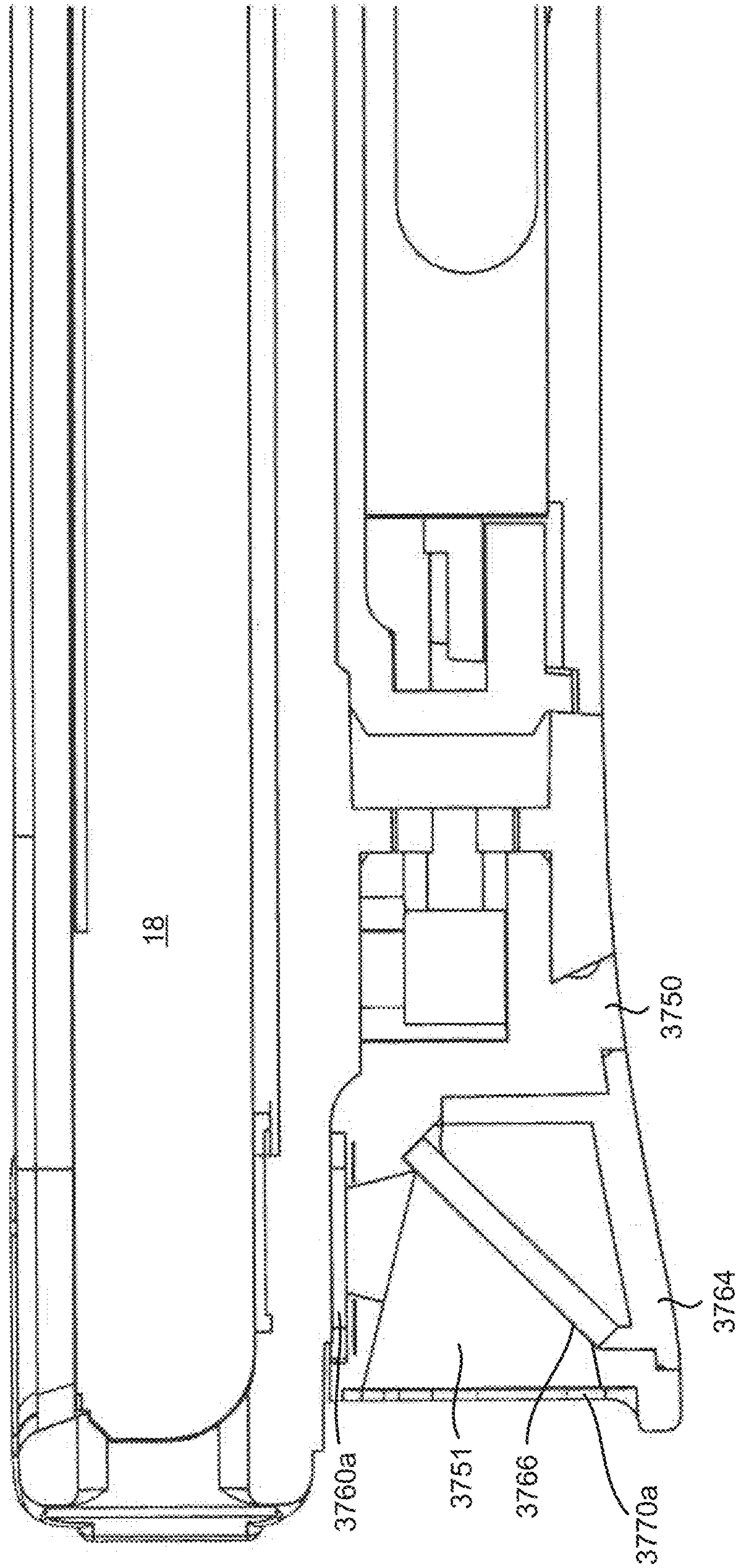


FIG. 40A

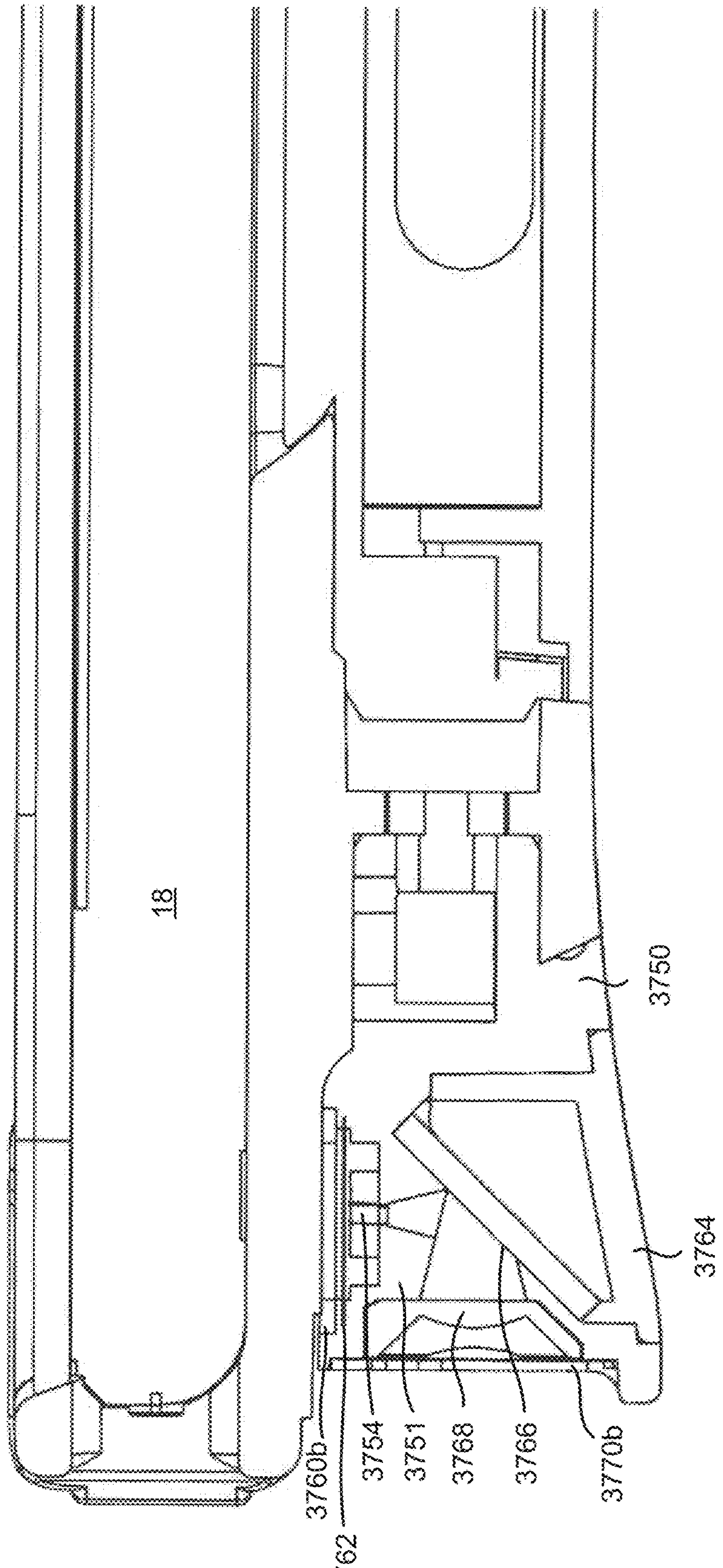


FIG. 40B

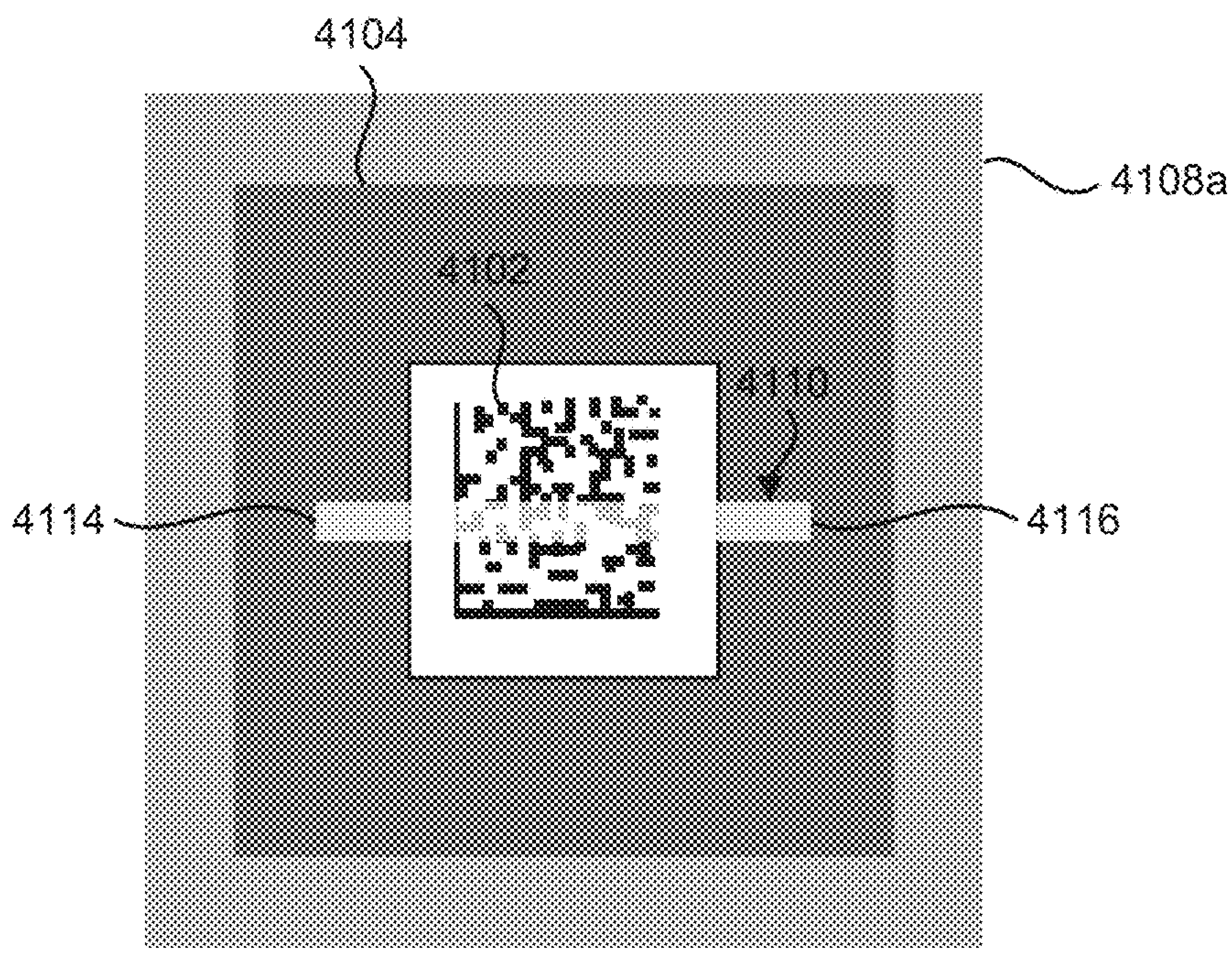


FIG. 41A

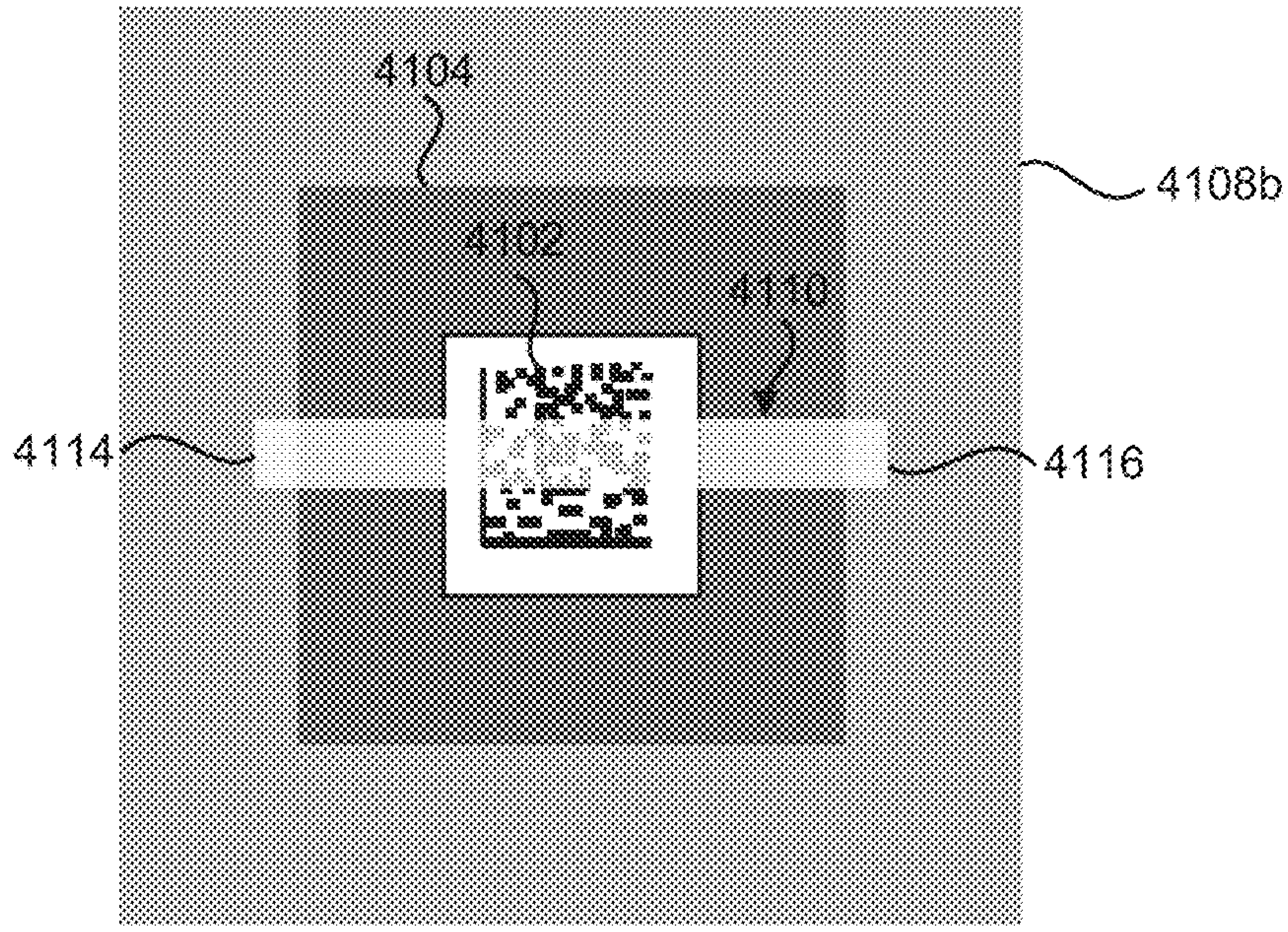


FIG. 41B

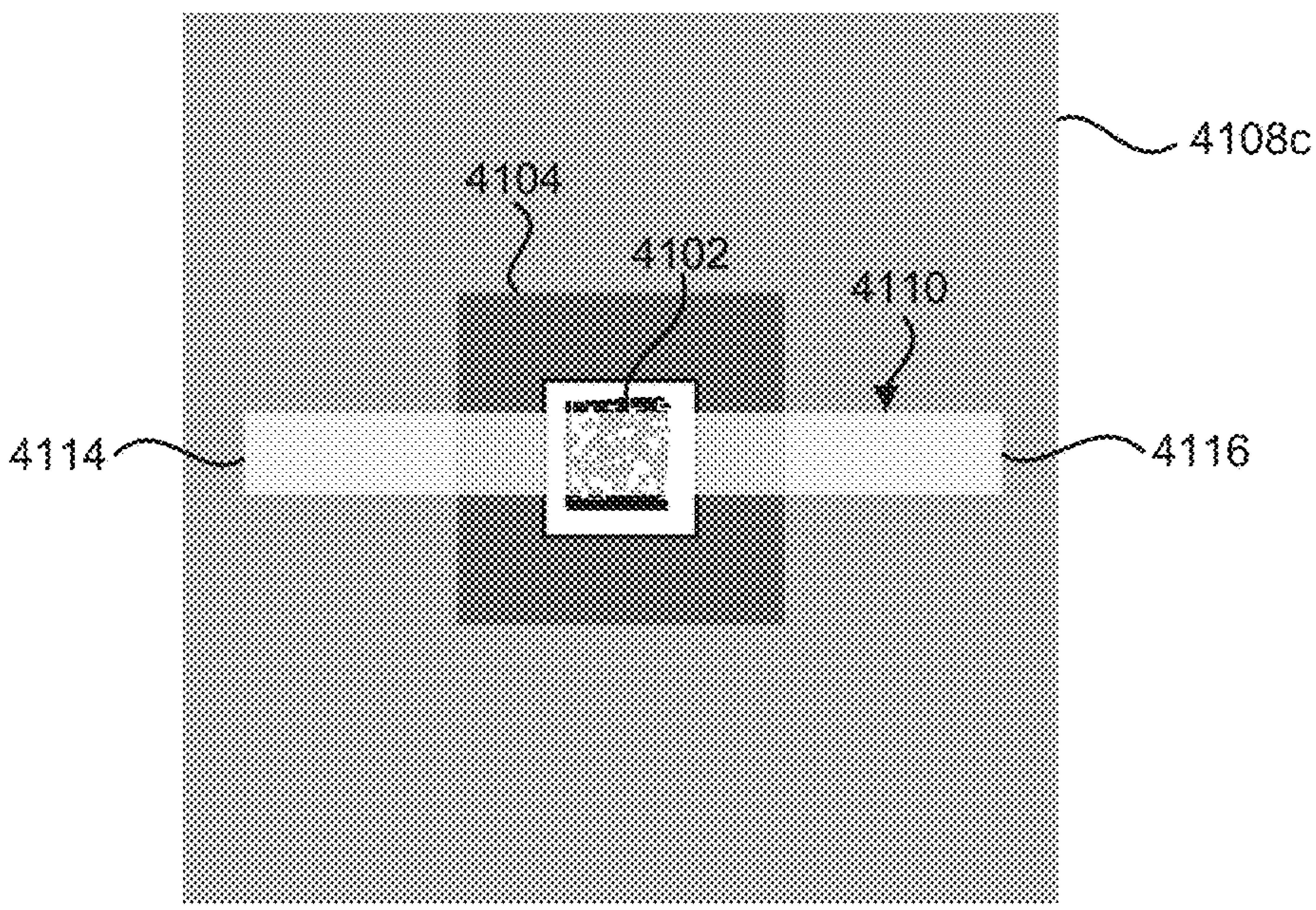


FIG. 41C

4218

Surface Distance	Feature Offset
D_1	O_1
D_2	O_2
D_3	O_3
D_4	O_4
D_5	O_5
⋮	⋮

FIG. 42

4318

Surface Distance	1st Location	2nd Location	Feature Offset
D_1	$(x_1, y_1)_1$	$(x_2, y_2)_1$	O_1
D_2	$(x_1, y_1)_2$	$(x_2, y_2)_2$	O_2
D_3	$(x_1, y_1)_3$	$(x_2, y_2)_3$	O_3
D_4	$(x_1, y_1)_4$	$(x_2, y_2)_4$	O_4
D_5	$(x_1, y_1)_5$	$(x_2, y_2)_5$	O_5
⋮	⋮	⋮	⋮

FIG. 43

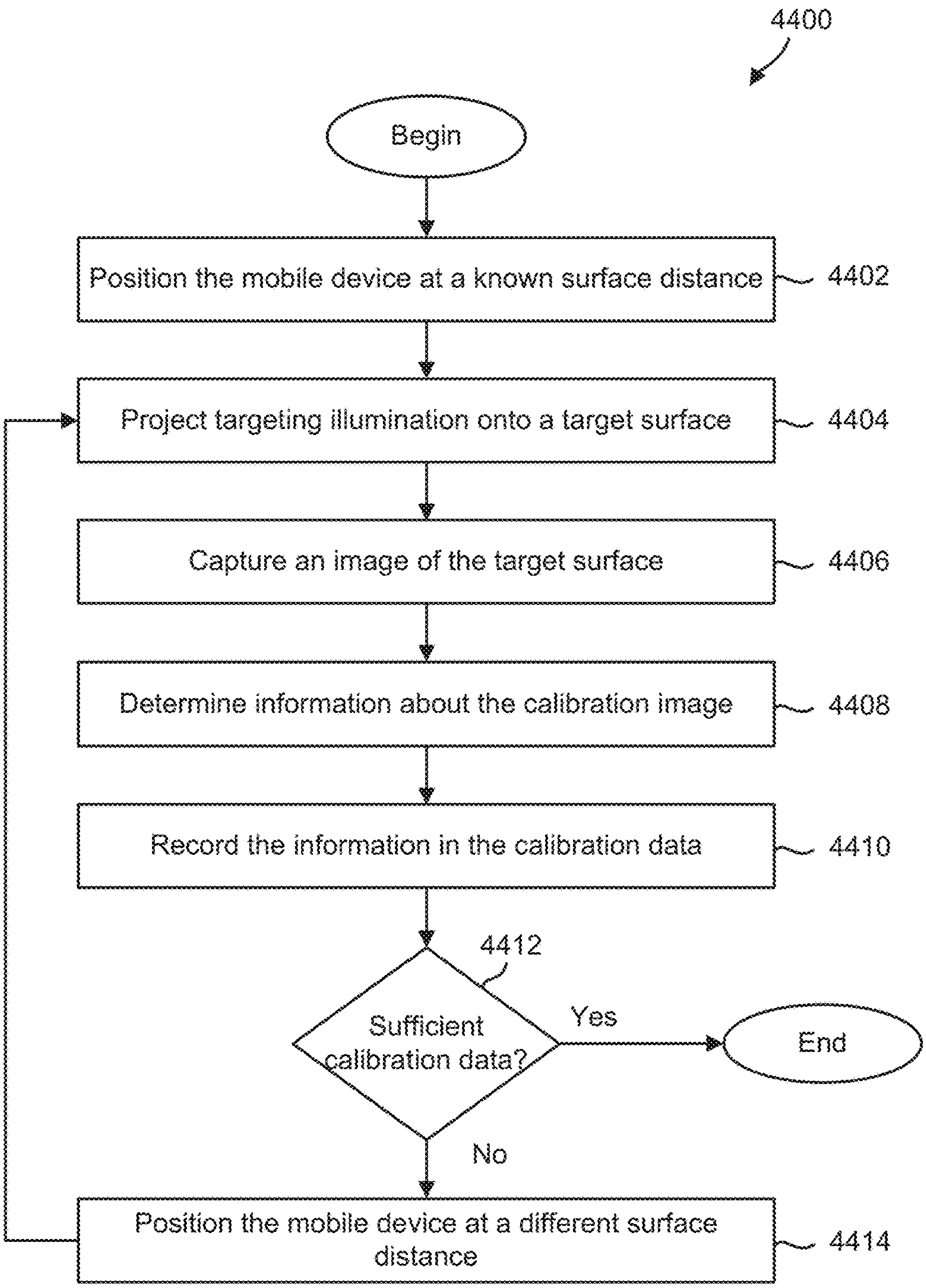

4400
Begin
Position the mobile device at a known surface distance
4402
Project targeting illumination onto a target surface
4404
Capture an image of the target surface
4406
Determine information about the calibration image
4408
Record the information in the calibration data
4410
4412
Sufficient calibration data?
Yes
End
No
Position the mobile device at a different surface distance
4414

FIG. 44

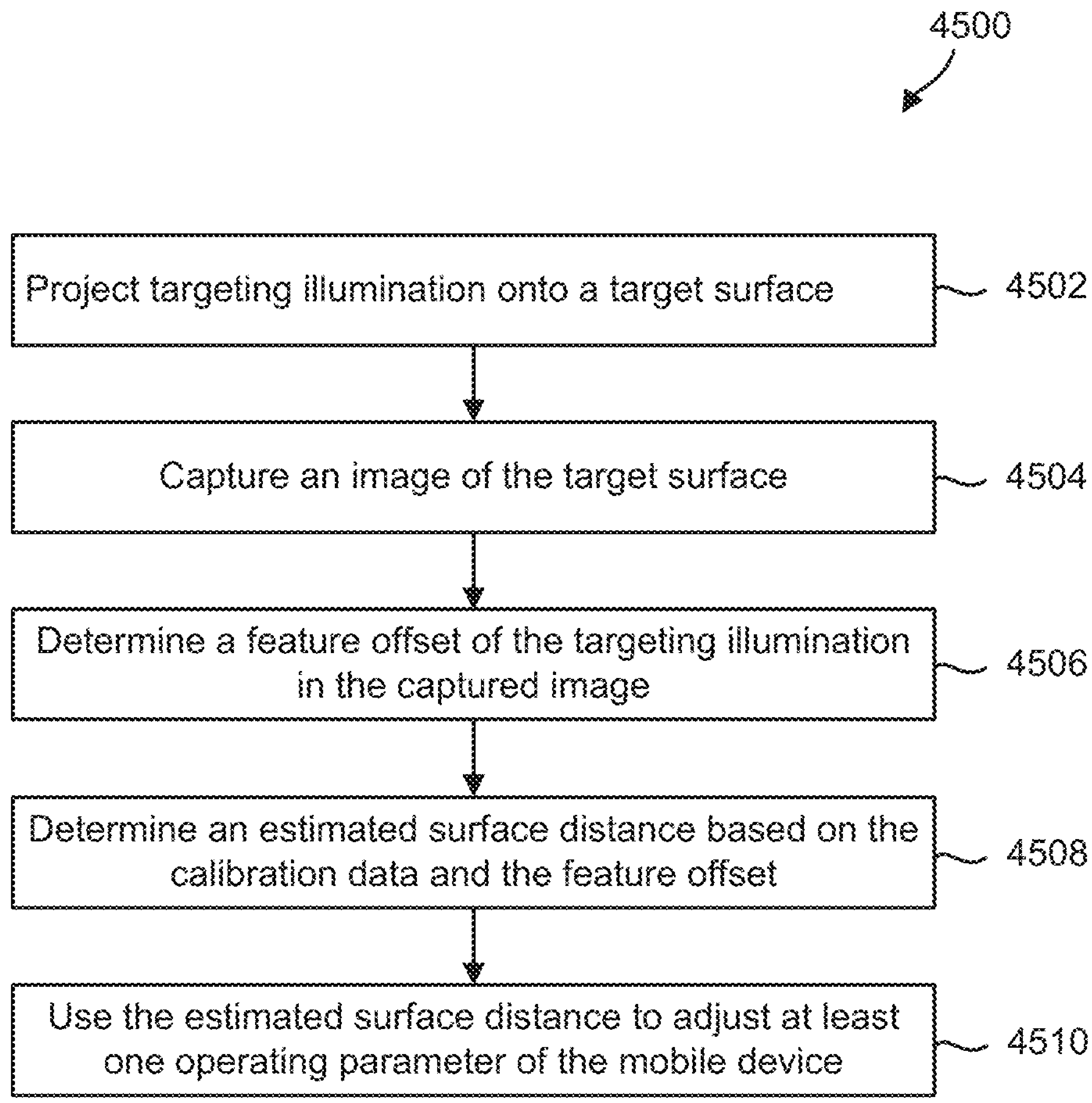

4500
Project targeting illumination onto a target surface
4502
Capture an image of the target surface
4504
Determine a feature offset of the targeting illumination in the captured image
4506
Determine an estimated surface distance based on the calibration data and the feature offset
4508
Use the estimated surface distance to adjust at least one operating parameter of the mobile device
4510

FIG. 45

BARCODE-READING SYSTEM THAT OBTAINS RANGING DATA VIA TARGETING ILLUMINATION

RELATED APPLICATIONS

The present application is a continuation of U.S. patent application Ser. No. 15/936,044 (the '044 application), filed on Mar. 26, 2018, titled "BARCODE-READING SYSTEM THAT OBTAINS RANGING DATA VIA TARGETING ILLUMINATION". The '044 application is a continuation of U.S. patent application Ser. No. 15/621,239, filed Jun. 13, 2017, titled "BARCODE-READING SYSTEM THAT OBTAINS RANGING DATA VIA TARGETING ILLUMINATION", which issued as U.S. Pat. No. 9,928,392 (the '392 patent) on Mar. 27, 2018. The '392 Patent is a continuation-in-part of U.S. patent application Ser. No. 15/207,484, filed Jul. 11, 2016, which issued as U.S. Pat. No. 9,665,760 (the '760 patent) on May 30, 2017, and titled "BARCODE-READING SYSTEM". The '760 patent claims priority to Provisional Patent Application No. 62/318,216, filed Apr. 5, 2016, and titled "BARCODE-READING SYSTEM". The '760 patent is also a continuation-in-part of U.S. patent application Ser. No. 14/304,830, filed Jun. 13, 2014, which issued as U.S. Pat. No. 9,679,175 on Jun. 13, 2017, and titled "BARCODE READER RANGING USING TARGETING ILLUMINATION".

BACKGROUND

Smartphones and other types of portable, hand-held computing devices, such as tablet computers, are in widespread use today, most often in connection with entertainment, communications and office productivity. Most smartphones include a camera, and applications have been developed for using the camera to read barcodes. In a typical known application an image feed from the camera is displayed on the display screen of the smartphone.

SUMMARY

In accordance with the present disclosure, a barcode-reading system for a mobile device is disclosed. The mobile device may include a camera assembly and a white light source for providing illumination. The barcode-reading system may include a barcode-reading enhancement accessory, calibration data, and a barcode-reading application. The barcode-reading enhancement accessory may be securable to the mobile device. The barcode-reading enhancement accessory may include an optic system that is positionable within a field of illumination of the white light source when the barcode-reading enhancement accessory is secured to the mobile device. The optic system may be configured to shape and filter the illumination from the white light source to project targeting illumination onto a target surface. The calibration data may indicate a relationship between surface distance and at least one feature offset of the targeting illumination. The barcode-reading application may be stored in memory of the mobile device. The barcode-reading application may be executable by a processor of the mobile device to determine a feature offset of the targeting illumination in an image that is captured by the camera assembly of the mobile device. The barcode-reading application may also be executable to determine an estimated surface distance based on the calibration data and the feature offset. The barcode-reading application may also be executable to use

the estimated surface distance to adjust at least one operating parameter of the mobile device.

Adjusting the at least one operating parameter of the mobile device may include adjusting intensity of the illumination provided by the white light source of the mobile device.

The targeting illumination may include a rectangular targeting bar. Determining the feature offset may include determining a width of the rectangular targeting bar.

The optic system may include an optical filter that is configured to pass a limited spectrum of the illumination emitted by the white light source. The image may include a plurality of channel images. A channel image of the plurality of channel images may be used to determine the feature offset of the targeting illumination. The channel image may be more sensitive to the limited spectrum that is passed by the optical filter than other channel images of the plurality of channel images.

The calibration data may include a plurality of surface distance fields and a plurality of feature offset fields. Each feature offset field may be associated with a corresponding surface distance field.

Determining the estimated surface distance may include identifying a feature offset field whose value is closest to the feature offset in the image and returning a value of a corresponding surface distance field as the estimated surface distance.

Determining the estimated surface distance may include interpolating the estimated surface distance using the calibration data and the feature offset in the image.

The calibration data may include a plurality of records. Each record may include a surface distance field that indicates a surface distance, a second location field that indicates a location of a second feature of the targeting illumination in the calibration image, and a feature offset field indicating a difference between the location of the first feature of the targeting illumination in the calibration image and the location of the second feature of the targeting illumination in the calibration image.

The calibration data may include a mathematical formula that receives, as an input, the feature offset of the targeting illumination. The calibration data may also include a mathematical formula that provides, as output, the estimated surface distance.

The barcode-reading application may be configured to cause the camera assembly to capture a plurality of calibration images and record information about the plurality of calibration images in the calibration data.

A barcode-reading application for a mobile device is also disclosed. The barcode-reading application may include a processor, memory, a camera assembly, and a white light source for emitting illumination. The barcode-reading application may include executable code. When stored in the memory executed by the processor, the executable code may determine a feature offset of targeting illumination in an image that is captured by the camera assembly of the mobile device. The targeting illumination may be produced by an optic system of a barcode-reading enhancement accessory that is secured to the mobile device. The executable code may also determine an estimated surface distance based on the calibration data and the feature offset. The executable code may also use the estimated surface distance to adjust at least one operating parameter of the mobile device.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates an example of a barcode-reading system.

FIG. **2A** is a block diagram of an exemplary mobile device useful in a barcode-reading system.

FIGS. **2**B and **2**C show a back side surface and a face surface of an exemplary mobile device that may be used in the barcode-reading system.

FIG. **2**D shows an exemplary tip/ring/ring/sleeve (TRRS) connector.

FIG. **2**E shows an image output format.

FIG. **3**A is a flow diagram of an exemplary process for an operation of an application retrieval system.

FIG. **3**B is a flow diagram depicting an exemplary process for an operation of an application server.

FIG. **3**C shows an exemplary structure of a database of applications for downloading.

FIGS. **4**A and **4**B illustrate an exemplary corner-positioned attachment useful in a barcode-reading enhancement system.

FIGS. **5**A and **5**B illustrate an exemplary encapsulating attachment useful in a barcode-reading enhancement system.

FIGS. **6**A and **6**B illustrate an exemplary mounted attachment useful in a barcode-reading enhancement system.

FIGS. **7**A and **7**B illustrate an exemplary target-generating mechanism useful for implementing in an attachment in a barcode-reading enhancement system.

FIGS. **8**A-**8**D illustrate exemplary targeting patterns useful for implementing in an attachment of a barcode-reading enhancement system.

FIG. **9** illustrates an exemplary exposure illumination system useful for implementing in an attachment of a barcode-reading enhancement system.

FIGS. **10**A-**10**D illustrate exemplary supplementary optics useful for implementing in an attachment of a barcode-reading enhancement system.

FIGS. **11**A and **11**B illustrate an exemplary attachment for a barcode-reading enhancement system which includes a target-generating mechanism and supplementary optics.

FIGS. **12**A-**12**D illustrate an exemplary attachment for a barcode-reading enhancement system which includes a target-generating mechanism.

FIG. **13** illustrates an exemplary attachment for a barcode-reading enhancement system with a target-generating mechanism, an exposure illumination system and supplementary optics useful for implementing in an attachment of a barcode-reading enhancement system.

FIG. **14** illustrates an exemplary attachment for a barcode-reading enhancement system.

FIG. **15** illustrates an exemplary attachment for a barcode-reading enhancement system which includes a target-generating mechanism and supplementary optics.

FIG. **16** illustrates exemplary methods useful for an application for a barcode-reading enhancement system.

FIG. **17** illustrates an exemplary state machine useful for an application for a barcode-reading enhancement system.

FIG. **18**A illustrates exemplary autofocus options.

FIG. **18**B illustrates exemplary resolution binning methods that can be used to reduce the resolution of a barcode image.

FIG. **19**A depicts an exemplary method of target and exposure illumination and shutter control in accordance with one embodiment.

FIG. **19**B depicts another exemplary method of target and exposure illumination and shutter control in accordance with another embodiment.

FIG. **19**C represents a filtering arrangement for the targeting illumination and the supplemental optics.

FIG. **20**A is a state machine diagram depicting two states of operation in a barcode-reading application in accordance with one embodiment.

FIG. **20**B is a state machine diagram depicting three states of operation in a barcode-reading application in accordance with another embodiment.

FIG. **21** shows examples of a data structure of a license key in accordance with some embodiments.

FIG. **22**A depicts an exemplary operation of a license server.

FIG. **22**B depicts an exemplary operation of a license server for renewing a license for a mobile device prior to expiration of the license.

FIG. **22**C depicts an exemplary database for recording pre-paid licenses that may have been purchased by an individual, organization, company or other group of users.

FIG. **23** is an exploded view of an exemplary barcode-reading enhancement accessory configured as an encapsulating attachment.

FIGS. **24**A and **24**B are sectional views of the case encasing a mobile device.

FIG. **25** shows an exemplary outer case and exemplary inner carriages that may be accommodated in the outer case.

FIG. **26** shows an exemplary barcode-reading enhancement accessory configured as an encapsulating attachment in accordance with another embodiment.

FIG. **27** shows the barcode-reading enhancement accessory of FIG. **26** with a mobile device encased into the cavity of the case.

FIG. **28** shows the combined state of the case and the handle assembly of the barcode-reading enhancement accessory of FIG. **26**.

FIG. **29** is a cutaway view of an accessory with the handle assembly assembled with a case to encase a mobile device.

FIG. **30** shows another exemplary barcode-reading enhancement accessory configured as an encapsulating attachment in accordance with another embodiment.

FIG. **31** depicts a case and a platform of another exemplary barcode-reading enhancement accessory along with a mobile device.

FIG. **32** shows an exemplary barcode-reading enhancement accessory with a different latching mechanism.

FIG. **33** shows an exemplary case coupled to a platform, which is configured as an encapsulating attachment.

FIG. **34** depicts an exemplary image processing method for capturing a barcode while a targeting illumination is on.

FIG. **35**A shows a composite image of the first, second, and third channel images.

FIGS. **35**B-**35**D show first channel, second channel and third channel images, respectively.

FIGS. **36**A and **36**B show a grayscale image resulting from combining the first, second, and third channel images with different combining ratios.

FIGS. **37**A-**37**C depict a perspective view of a mobile device encapsulated within an encapsulating attachment in accordance with one embodiment.

FIG. **38** depicts an encapsulating attachment in accordance with another embodiment.

FIGS. **39**A and **39**B are an assembled view and an exploded view of an optics module, respectively.

FIGS. **40**A and **40**B are cross-sectional views of the optics module along the A-A' and B-B' lines shown in FIG. **39**A.

FIGS. **41**A-**41**C illustrate images of targeting illumination projected by an accessory onto a target surface at three different surface distances.

FIG. **42** is a table illustrating calibration data in accordance with an embodiment in which the calibration data is stored in a lookup table.

FIG. **43** is a table illustrating calibration data in accordance with another embodiment in which the calibration data is stored in a lookup table.

FIG. **44** is a flowchart illustrating a method for determining calibration data.

FIG. **45** is a flowchart illustrating a method for obtaining ranging data in accordance with an embodiment

DETAILED DESCRIPTION

FIG. **1** depicts a system **10** according to one embodiment of the present application wherein mobile devices **18***a*-**18***d* obtain: i) at least one barcode-reading application **24** from an application server **22***a* or **22***b*; and ii) obtain licensing (e.g., a license key **26**) necessary for the operation of the at least one barcode-reading application **24** on the mobile devices **18***a*-**18***d* from a licensing server **21***a* or **21***b*.

As used in this patent specification and the accompanying claims, the term "mobile device" will be used to describe a portable, hand-held computing device that comprises a camera. As indicated above, one example of a mobile device is a smartphone. Another example of a mobile device is a tablet computer. Yet another example is a hybrid tablet/smartphone device, often nicknamed a "phablet."

The application server may be, for example, a local application server **22***a* or a remote application server **22***b*. Similarly, the license server may be a local license server **21***a* or a remote license server **21***b*. The application server and the license server may operate on distinct hardware or may operate on the same hardware server. For example, the local application server **22***a* and the local license server **21***a* may operate on the same hardware server **27** or on distinct hardware servers, each coupled to a local area network (LAN) **12**. Similarly, the remote application server **22***b* and the remote license server **21***b* may operate on the same hardware server **29** or on distinct hardware servers, each coupled to the Internet **16**.

The system **10** may include a LAN **12** to which each of the local application server **22***a* and the local license server **21***a* are connected. The LAN **12** may further include at least one wireless access point **14** enabling LAN communications with mobile devices (for example, mobile devices **18***b* and **18***c*) as well as other computing systems such as a host computer **19** and/or a charging station **21** (e.g. a station for providing power to the mobile device **18** for charging its battery).

The LAN **12** may be coupled to the Internet **16** via a router **13**. Although FIG. **1** depicts the LAN **12** coupled to the Internet **16** via a single router **13**, such connections may employ multiple routers and firewall systems, including demilitarized zone (DMZ) networks.

Referring to FIG. 2A in conjunction with FIG. **1**, each of the mobile devices **18***a*-**18***d* may include a wireless communication system **52** for operating within a wireless network environment. The wireless communication system **52** may comprise any permutation of: i) a local area network (LAN) communications module **56**, ii) a wide area network (WAN) communications module **54**, and/or iii) a wireless point-to-point communication interface **58**.

The LAN communications module **56** may utilize Wi-Fi™ (IEEE 802.11) or similar wireless local area communication protocols for communication with a wireless access point **14** of a wireless portion of a LAN **12**, such that the mobile device itself may be an addressable endpoint on the LAN **12**, i.e., the mobile device may be assigned an IP address and may be capable of IP communications with other devices over the LAN **12** using IP protocols such as Transmission Connection Protocol (TCP), Uniform Datagram Protocol (UDP), etc. The wireless access point **14** and the LAN communications module **56** may function in accordance with any known wireless communications protocol, including but not limited to the IEEE 802.11 standards, which are sometimes referred to as Wi-Fi™. As will be discussed in more detail, a mobile device, **18***b* for example, utilizing its LAN communications module **56** may obtain at least one barcode-reading application **24** from an application server **22***a* or **22***b* and its license key from a license server **21***a* or **21***b* via the LAN **12** and, as applicable, the Internet **16**.

The WAN communications module **54** may utilize Wideband Code Division Multiple Access (WCDMA), High Speed Packet Access (HSPA), cdma2000, Long Term Evolution (LTE) technology, or other similar long-range wireless communication protocols for communication with a wide area wireless Internet service provider (ISP). For example, the ISP may be a mobile telephone service provider and the wireless WAN communications module **54** may be a system for wireless data communications with the access towers of the wireless ISP network **17** (i.e., WAN). Such wireless data communications may occur in accordance with any suitable wireless communication standard, including Third Generation (3G) standards (e.g., Universal Mobile Telecommunication Systems (UMTS), cdma2000, Enhanced Data Rate for GSM Evolution (EDGE), etc.) and/or Fourth Generation (4G) standards (e.g., LTE, Mobile WiMAX, etc.). The wireless ISP network **17** may assign an IP address to the mobile device such that the mobile device may be capable of IP communications with other devices over the wireless ISP network **17** using IP protocols such as TCP, UDP, or the like.

Remote devices (e.g., devices coupled to the Internet **16**) may be logically connected to the LAN **12** using a Virtual Private Network (VPN) technology. As such, a mobile device, **18***d* for example, coupled to communicate with the wireless ISP network **17** utilizing its WAN communications module **54** may, utilizing a VPN technology, be an endpoint on the LAN **12**. As such, a mobile device **18** may obtain at least one barcode-reading application **24** from the remote application server **22***b* (or local application server **22***a* utilizing VPN technologies) and its license key **26** from the remote license server **21***b* (or the local license server **21***a* utilizing VPN technologies) via the wireless ISP network **17** and, as applicable, the Internet **16**.

The wireless point-to-point communication interface **58** may form a wireless point-to-point communication link with another compatible system, such as a host computer **19** and/or charging station **21**, utilizing Bluetooth® or similar wireless point-to-point communication protocols. The host computer **19** and/or charging station **21** in turn includes a wired and/or wireless LAN interface for communication with a switch (not shown) or the wireless access point **14** of the LAN **12** such that the host computer **19** may be an addressable endpoint on the LAN **12**. As will be discussed in more detail, a mobile device, **18***a* or **18***c* for example, coupled to communicate with the host computer **19** utilizing its wireless point-to-point communication interface **58** may obtain at least one barcode-reading application **24** from an application server **22***a* or **22***b* and its license key **26** from a license server **21***a* or **21***b* via its point-to-point connection to the host computer **19** and/or charging station **21** which communicates with the servers via the LAN **12** and, as applicable the Internet **16**.

FIGS. **2**B and **2**C illustrate a back surface and a face surface of an exemplary mobile device **18**, respectively.

Referring to FIGS. **2**B and **2**C, the mobile device **18** may comprise a housing **28** with a plurality of external surfaces such as a face surface **72** and a back surface **74** which is generally parallel to the face surface **72** and separated from the face surface **72** by four (4) edge surfaces (each orthogonal to, and extending about the perimeter of, both the face surface **72** and the back surface **74**, including a bottom edge **76**, a top edge **78** (which is parallel to the bottom edge **76**), a right edge **80** and a left edge **82** (which is parallel to the right edge **80**).

The face surface **72** may include a user interface such as a capacitive multi-touch display screen **66** (e.g., with a glass cover), which is shown in FIG. **2**A, and may define the face surface **72** of the housing **28**.

Referring to FIG. **2**C, the nomenclature bottom edge **76**, top edge **78**, right edge **80**, and left edge **82** have been chosen because they correspond to the bottom, top, right, and left sides of the display screen **66** of the face surface when the display screen **66** is operated in a portrait mode. Each of the right edge **80** and the left edge **82** may be of equal length and longer than each of the bottom edge **76** and the top edge **78** (which may also be of equal length).

Referring to FIG. **2**A, the mobile device **18** may include a processor **44** and a memory **46**. The processor **44** may be embodied as a combination of one or more microprocessors, microcontrollers, digital signal processors (DSP), or the like, and, when operating, may execute instructions (in the form of an operating system and/or applications) stored in the memory **46**. The memory **46** may be any component capable of storing electronic information, including an operating system and/or application instructions executable by the processor **44**, and may be embodied as read-only memory (ROM), random access memory (RAM), magnetic disk storage media, optical storage media, flash memory devices, on-board memory included with the processor **44**, erasable programmable read-only memory (EPROM), electrically erasable programmable read-only memory (EEPROM), and/or registers, etc.

The memory **46** may include an operating system **48**, the barcode-reading application **24**, the license key **26**, one or more other applications **50***a*, **50***b*, and a data buffer including an image data buffer **89**. In operation, the processor **44** may execute instructions embodied in the operating system **48**, the barcode-reading application **24**, and each of the other applications **50***a*, **50***b*. Hardware circuits **90** interface the processor **44** with peripheral systems including, but not limited to, a (multi-touch) display screen **66**, a wireless communication system **52**, a hardwired point-to-point communication interface **60**, an audio interface **68**, a camera assembly **36**, and a white light source **84** (e.g., an illuminator or a flash for utilizing the camera assembly **36** for photography).

The hardwired point-to-point communication interface **60** may utilize Universal Asynchronous Receiver/Transmitter (UART), Universal Serial Bus (USB), and similar communication protocols for communicating with a compatible system connected to a data connector **64***b* (which may be a part of a single power/data connector **64** such as a USB connector or an Apple® Lightning Connector®).

The audio interface **68** may include circuits for generating analog audio signals on a speaker connector **34***a* and receiving analog microphone input on a microphone connector **34***b*. The speaker connector **34***a* and the microphone connector **34***b* may be embodied as a single tip/ring/ring/sleeve (TRRS) connector typically referred to as a head-set connector. FIG. **2**D shows an exemplary (female) TRRS connector. The TRRS connector includes four contacts: tip contact **71***a*, ring **1** contact **71***b*, ring **2** contact **71***c*, and sleeve contact **71***d*, along the side of recesses **69***a*, **69***b*, **69***c*, and **69***d*, which contact the corresponding contacts of the (male) TRRS connector of an audio jack when inserted within the recess. Typically the contacts are for left audio, right audio, microphone, and ground in the order of tip, ring **1**, ring **2**, and sleeve. A microphone input signal may be a potential difference between the ground contact (sleeve) and the microphone contact (ring **2**) generated by a microphone coupled thereto.

Referring to FIG. **2**A, the camera assembly **36** may include a (color) photo sensor **42** (i.e., an array of image sensors) positioned parallel to each of the face surface **72** and the back surface **74** and a lens assembly **40** with an optical axis **39** orthogonal to the photo sensor **42** and defining a center line of a camera field of view **38** extending outward from the back surface **74** of the mobile device **18**. The photo sensor **42** may include one or more sensors such as charge-coupled display (CCD) sensors, complementary metal-oxide-semiconductor (CMOS) sensors, or the like.

The lens assembly **40** may receive light reflected from objects within the camera field of view **38**. The camera field of view **38** may have an angular size **41** which may be the angle at which the camera field of view **38** spreads with respect to distance from the lens assembly **40**. The lens assembly **40** may have a camera aperture size measured as an f-number which is the ratio of the focal length of the lens assembly **40** to the diameter of the entrance pupil (i.e., the lens aperture (an aperture stop or an inherent aperture of the lens component defining the aperture) as viewed through the front of the lens assembly **40**).

The camera assembly **36** may further include an auto zoom module **96** and/or an autofocus module **98** which may serve to control an optical zoom setting and/or autofocus setting of the camera, respectively. Autofocus and auto zoom may be controlled by moving the position of at least one of the lenses making up the lens assembly **40** with respect to each other (or with respect to the photo sensor **42**) and/or altering the curvature of at least one of the lenses making up the lens assembly **40**.

In general, the camera lens assembly **40** and the autofocus module **98** (which compensates for limited depth of field at larger apertures) and the auto zoom module **96** (which adjusts the angular size **41** and image magnification) are designed and/or optimized for general-purpose photography, and may therefore not be ideal for barcode capture and/or decoding. More specifically, in a barcode-reading application an operator expects to read and decode a barcode in less than 300 ms. The focus and zoom adjustment process may require significantly more time and therefore, if used, it would significantly delay the response time in a barcode-reading application.

If the camera lens assembly **40** is fixed (e.g., not adjusted for focus and zoom) at any particular focus and/or zoom setting for the lens assembly **40**, the combination of the angular size **41** and the camera aperture size affect the camera depth of field (e.g., the range of distances at which a barcode of a particular modular size is imaged onto the photo sensor with sufficient size and sharpness for decoding). The angular size **41** affects the minimum distance at which a barcode of a certain overall size can be imaged onto the photo sensor **42**.

The photo sensor **42** may be coupled to system-on-chip circuits **92** which include an output module **91** and an auto-white balance module **93**. In one embodiment, the output module **91** may control the operation of the photo sensor **42** (e.g., exposure, gain, and coupling of pixels to analog-to-digital (A/D) converters for image read out), format the digital intensity values of each pixel of the photo sensor **42** for color image output, and make the color image output available for writing to the image data buffer **89**.

In another embodiment, the output module **91** may perform image processing on images captured by the photo sensor **42**. Control of the photo sensor **42** and image pre-processing which may be performed by the system on chip circuits **92** are described in more detail in U.S. patent application Ser. No. 14/717,112, entitled "BARCODE READER" and filed on May 20, 2015, which is hereby incorporated by reference in its entirety.

The auto-white balance module **93** may perform auto-white balance algorithms on the captured image to enhance the quality of color photographs captured by the photo sensor **42** under different illumination conditions. The digital image output **162** (which may be the color image or a result of processing the image one or more times in accordance with the teachings of U.S. patent application Ser. No. 14/717,112) may be written to the image data buffer **89**. The mobile device **18** may include a direct memory access (DMA) system **86** which may be a part of the processor **44**. The DMA **86** provides for direct writing of the digital image output **162** from the camera assembly **36** to the image data buffer **89**.

The camera assembly **36** may further include a white light source **84**. The white light source **84** may include one or more LEDs **84***a*, **84***b* controlled by the system-on-chip circuits **92**.

In an exemplary embodiment, a first LED **84***a* may be a white LED. The color of a white LED is typically described using a Kelvin temperature scale with 1500° K representing a warm color "white," such as that of candlelight, and 9500° K representing a cool color "white," such as that of a blue sky. The exemplary white LED may be within this range. Alternatively, the exemplary white LED may have a color between 4000° K and 7000° K.

In the exemplary embodiment the second LED **84***b* may be an amber LED emitting illumination within the 600-615 nm range. Both the first LED **84***a* and the second LED **84***b* may be positioned behind a common optic **85** which directs illumination within a field of illumination **83** projecting away from the back surface **74** and having an illumination axis **88** perpendicular to the back surface **74** and an illumination angle **87** which substantially coincides with the field of view **38** of the camera assembly **36**. In operation, the system-on-chip circuits **92** may control each LED **84***a*, **84***b* independently; and control the intensity of each LED **84***a*, **84***b* independently such that the color of the white illumination of the combined LEDs may be controlled by controlling the intensity of the amber LED with respect to the intensity of the white LED. If the intensity of the amber LED is higher, the white color of the combination will be warmer (lower Kelvin temperature). If the intensity of the amber LED is lower, the color approaches the Kelvin temperature of the white LED alone.

FIG. **2**E shows two exemplary image output formats. The image output format from the photo sensor **42** (or from the output module **91** prior to any image processing as described in U.S. patent application Ser. No. 14/717,112) may be in either R.G.B. format **164** and/or Y.U.V format **166**. The Y.U.V. format **166** may include, for each pixel, a luminous intensity **168** indicative of the overall intensity of light incident on the pixel during the exposure period, a first chromatic **170** representative of a first dimension of color of the light incident on the pixel during the exposure period, and a second chromatic **172** representative of a second dimension of color incident on the pixel during the exposure period.

The R.G.B. format **164** may include, for each pixel, a red intensity value **174** indicating the intensity of red light incident on the pixel during the exposure period, a green intensity value **176** indicating the intensity of green light incident on the pixel during the exposure period, and a blue intensity value **178** indicating the intensity of blue light incident on the pixel during the exposure period.

Returning to FIG. **2**A, the mobile device **18** may further include a battery **62** and power circuits **63**. In general the power circuits **63** control charging of the battery **62** from power received from an external power source via the power connector **64***a* and providing operating power at the voltage and current drawing requirements of the various components of the mobile device **18** from the power received from the battery **62** or the external power source (when connected to the external power source).

Referring to FIG. **2**A in conjunction with FIG. **1**, in an exemplary embodiment, the operating system **48** may include an application retrieval system **49** which obtains the barcode-reading application **24** and the applications **50***a*, **50***b* from the application server **22***a* or **22***b*. In one embodiment, the operation of the application retrieval system **49**, which may obtain the barcode-reading application **24** and the other applications **50***a*, **50***b* from the application server **22***a* or **22***b*, may be the exclusive means for loading, writing, or otherwise placing the barcode-reading application **24** and the other applications **50***a*, **50***b* into the memory **46**. The operating system **48** may be configured to block or prevent loading of any applications to the memory **46** by any means other than the operation of the application retrieval system **49** in a manner such that the applications **24**, **50***a*, **50***b* may be retrieved exclusively from the application server **22***a* or **22***b*.

FIG. **3**A is a flow diagram of an exemplary process for the operation of the application retrieval system **49**. Step **180** represents the application retrieval system **49** of the mobile device **18** establishing a secure connection to the application server **22***a* or **22***b* over the LAN **12**, the wireless ISP network **17** and/or the Internet **16** and authenticating the application server **22***a*, **22***b* (i.e., mutual authentication between the mobile device and the application server). The mutual authentication may be established by using any conventional authentication protocol.

Step **182** represents rendering, on the display screen **66** of the mobile device **18**, identification of applications which are available to the mobile device **18** for downloading. Step **184** represents obtaining user selection of an application to download.

Step **186** represents obtaining an application file package (e.g., an install package) from the application server **22***a* or **22***b*. The application file package may be temporarily stored in the memory **46** of the mobile device **18**.

Step **188** represents installing the application. The installation process may include un-packing the install package and writing an executable application **50** to the memory **46**.

FIG. **3**B is a flow diagram depicting an exemplary process for operation of an application server **22***a*, **22***b*. Step **350** represents the application server **22***a*, **22***b* establishing a secure connection with the mobile device **18** over the LAN **12**, the wireless ISP network **17**, and/or the Internet **16** and authenticating the mobile device **18** and/or the user of the mobile device **18**. Authenticating the user of the mobile device **18** may include: i) authenticating the individual to which the mobile device **18** is assigned or the individual using the mobile device **18**, utilizing a combination of a user ID and a password or similar schemes for authenticating an individual, and/or ii) authenticating an organization, company, or other group of users to which the mobile device **18** is assigned, utilizing a combination of a user ID and a password or other similar schemes for identifying whether the mobile device **18** has been assigned to the organization, company, or group and authenticating the assignment. The user ID may be unique to each mobile device **18** or common for all mobile devices **18** assigned to the organization, company, or group.

Step **352** represents the application server **22***a*, **22***b* determining a plurality of one or more applications (the barcode-reading application **24**, applications **50***a*, **50***b*, etc.) available for download based on the individual, organization, company, or other group to which the mobile device **18** is assigned.

Turning briefly to FIG. **3**C, the application server **22***a*, **22***b* may contain, or have access to, a database **360** which identifies generally available applications **362** which are available to any mobile device **18** without regard to the identification of the user, organization, company, or group to which the mobile device **18** is assigned; and restricted applications **364** which are available only to certain individuals, organizations, companies, and groups. For restricted applications **364**, the database **360** may associate each user group **366***a*, **366***b* with identification of those restricted applications **368** available to that user group **366***a*, **366***b*. Each user group may be an individual, organization, company, or other group. For example, user group **1 366***a* may have access to restricted applications **368***a*, **368***b*, and **368***c*, and user group **2 366***b* may have access to restricted application **368***b*. In each case these restricted applications may be applications written custom for the user group (and therefore are not made available to other user groups) or may be licensed to the user group (and therefore made available to those user groups which obtained a license for the application).

Returning to FIG. **3**B, step **354** represents the application server **22***a*, **22***b* providing an indication of the available applications to the mobile device **18**. The available applications may include any of the generally available applications **362** and/or the restricted applications **364**. The indication of the available applications may include, for each application, a display screen icon representing the application. The indication of available applications may not include all available applications but may include only those available applications within parameters established by the user, for example available applications which meet search criteria provided by the user. As such, step **354** may include making a search function available to the mobile device **18**, obtaining search criteria or search terms from the user of the mobile device **18**, and selecting matching applications that meet the search criteria from the applications available to the individual, organization, company, or group.

Step **356** represents the application server **22***a*, **22***b* obtaining a user selection of a desired application. The desired application may be one of the available applications indicated to the user at step **354**.

Step **358** represents the application server **22***a*, **22***b* providing an application file package for the desired application to the mobile device **18**. The application file package may be provided to the application retrieval system **49** of the mobile device **18** which is provided for writing the file package to a non-volatile memory and unpacking and loading the contents of the file package to generate instructions which, when loaded to a memory, may be executed by the processor **44**.

Certain applications such as the barcode-reading application **24** may: i) require a license key from a license server **21***a*, **21***b* to enable operation of the application, ii) operate in a base mode of operation without a license key but require a license key from a license server **21***a*, **21***b* to enable at least one enhanced function to operate in an enhanced mode of operation, and/or iii) require a license key from a license server **21***a*, **21***b* to continue operating, or continue operating in the enhanced mode of operation, following the passage of time or following a threshold level of usage based on the time and/or the quantity of instances with which certain functions were performed (such as the quantity of decoding a barcode of a certain symbology or symbologies).

The at least one enhanced function may be a function of decoding a barcode symbology that the barcode-reading application **24** (e.g., the decoder) is restricted from decoding in the base mode of operation. Alternatively or additionally, the at least one enhanced function may be a function of decoding multiple barcodes in sequence at a rate that is faster than a rate at which the barcode-reading application **24** (e.g., the decoder) can decode multiple barcodes in sequence in the base mode of operation. Alternatively or additionally, the at least one enhanced function may be a function of decoding a quantity of barcodes of a particular symbology that exceeds a restricted threshold quantity of barcodes of the particular symbology that the barcode-reading application **24** (e.g., the decoder) can decode in the base mode of operation.

Alternatively or additionally, the at least one enhanced function may remove a demonstration restriction function (i.e., a demonstration factor that makes output of decoded data useful for demonstration purposes only) under which the barcode-reading application **24** functions in the base mode of operation. The demonstration restriction function may be at least one of: i) a function that scrambles decoded data from a barcode of at least one symbology, ii) a function that restricts the decoded data or scrambled decoded data from a barcode of at least one symbology from being made available for further processing, or iii) a function that restricts the decoded data or the scrambled decoded data from a barcode of at least one symbology from being displayed on a display screen of the mobile device **18**.

Alternatively or additionally, the at least one enhanced function may enable at least one enhanced image processing function that improves an ability to decode an image of a barcode and is not operable when the decoder operates in the base mode of operation. The enhanced image processing function may include preforming additional image processing algorithms which alter the image captured by the camera assembly **36** prior to execution of the algorithms which attempt to decode a barcode depicted within the image.

In accordance with another embodiment, the base mode of operation may include a base decoding mode of operation and a demonstration mode of operation. In the base decoding mode of operation, the barcode-reading application **24** may drive the camera assembly **36** to capture an image of a barcode and apply base decoder functions to the image to identify a barcode symbology. The barcode-reading application **24** may decode the barcode and make decoded data available for further processing if the barcode symbology is a base symbology, and enter the demonstration mode of operation if the barcode symbology is not the base symbology.

In the demonstration mode of operation, the barcode-reading application **24** may apply at least one enhanced barcode-reading function to decode the barcode, and perform at least one of: i) outputting an indication of successful decoding of the barcode, or ii) implementing a restriction function. The restriction function may be at least one of: i) a function that scrambles decoded data, ii) a function that restricts the decoded data or scrambled decoded data from being made available for further processing by at least one application executing on the mobile device, or iii) a function that restricts the decoded data or the scrambled decoded data from being displayed on a display screen of the mobile device **18**.

The barcode-reading application **24** may perform an upgrade function in the demonstration mode of operation. The upgrade function may enable user selection to obtain the license code, obtain the license code based on the user selection, establish a network connection to the licensing server **21***a*, **21***b*, and obtain the license code from the licensing server **21***a*, **21***b*.

In order to obtain the license code from the licensing server **21***a*, **21***b*, the barcode-reading application **24** may communicate to the licensing server **21***a*, **21***b* one of: i) a unique identification code of the mobile device **18**, or ii) a user identification code identifying a controller of the mobile device **18**.

In accordance with another embodiment, the barcode-reading application **24** (e.g., a decoder application) running on the processor **44** of the mobile device **18** may be configured to control the camera assembly **36** of the mobile device **18** to capture an image of a barcode. The image of the barcode may be affected by at least one optic system of the camera assembly **36**. The decoder application may utilize a base decoder function for attempting to decode a barcode if an enhanced decoder mode has not been authorized for the mobile device **18**, and utilize an enhanced decoder function for attempting to decode the barcode if the enhanced decoder mode has been authorized for the mobile device **18**.

The enhanced decoder function may include a function of decoding a barcode symbology that the decoder application is restricted from decoding if the enhanced decoder mode has not been authorized for the mobile device **18**. Alternatively or additionally, the enhanced decoder function may include a function of decoding multiple barcodes in sequence at a rate that is faster than a restricted rate at which the decoder application can decode a sequence of multiple barcodes if the enhanced decoder mode has not been authorized for the mobile device **18**. Alternatively or additionally, the enhanced decoder function may include a function of decoding a quantity of barcodes of a particular symbology that exceeds a restricted quantity of barcodes of the particular symbology which the decoder application can decode if the enhanced decoder mode has not been authorized for the mobile device **18**. Alternatively or additionally, the enhanced decoder function may remove a demonstration restriction function (i.e., a demonstration factor that makes output of decoded data useful for demonstration purposes) under which the decoder application functions when the enhanced decoder mode has not been authorized for the mobile device **18**, thereby making decoded data from a barcode of a particular symbology available for further processing by an application executing on the mobile device **18**. The demonstration restriction function may be at least one of: i) a function which scrambles decoded data from a barcode of at least one particular symbology, ii) a function which restricts the decoded data or scrambled decoded data from a barcode of at least one particular symbology from being made available for further processing by at least one application executing on the mobile device **18**, or iii) a function which restricts the decoded data or the scrambled decoded data from a barcode of at least one particular symbology from being displayed on a display screen of the mobile device **18**. Alternatively or additionally, the enhanced decoder function may enable at least one enhanced image processing function which improves an ability to decode an image of a barcode and is not operable if the enhanced decoder mode has not been authorized for the mobile device **18**. The enhanced decoder mode may be authorized by obtaining a license code from a licensing server **21***a*, **21***b*.

The decoder application may be configured to subject the license code to a predetermined algorithm to determine at least one operating permission authorized by the license code. The enhanced decoder function may correspond to the at least one operating permission authorized by the license code. The decoder application or any other application may be further configured to obtain the license code from the licensing server **21***a*, **21***b* by communicating to the licensing server one of: i) a unique identification code of the mobile device **18**, or ii) a user identification code identifying a controller of the mobile device **18**.

The barcode-reading application **24** (and the decoder application) disclosed above may be embodied on a computer-readable medium. The barcode-reading application **24** (and the decoder application) includes instructions executable by the processor **44** of the mobile device **18** for performing the functions disclosed above.

FIG. **20**A is a state machine diagram depicting two states of operation in a barcode-reading application **24** in accordance with one embodiment. The first state of operation may be a disabled state **474** (which may also be referred to as a base state). In the disabled state **474**, at least one function of the barcode-reading application **24** is disabled such that the barcode-reading application **24** may not output useful decoded data for further processing or transmission by the barcode-reading application **24** but may be capable of connecting to a licensing server **21***a*, **21***b* to obtain a license to transition the barcode-reading application **24** to a licensed operation state **476** (which may also be referred to as an enhanced operation state). The at least one function that may be disabled includes: i) an image capture function which, if enabled, would enable capturing an image of a barcode for image processing and decoding, ii) a decoding function which, if an image of a barcode is captured, would decode the image of the barcode to generate decoded data, iii) a data processing function which, if decoded data is generated, would process the decoded data as part of a useful workflow, and/or iv) a data transmission function which, if decoded data is generated and/or processed by the barcode-reading application **24**, would make the decoded data available to another local application (e.g., another application on the mobile device **18**) or a remote application (e.g., another application or database on any of the host computer **19**, a local server coupled to the LAN **12**, or a remote server coupled to the Internet **16**.

The licensed operation state **476** may enable the function(s) that is/are disabled when the barcode-reading application **24** is in the disabled state **474** such that the barcode-reading application **24** may be capable of capturing an image of a barcode for image processing and decoding, decoding the image of the barcode to generate decoded data, and performing, as applicable: i) a data processing function which, if decoded data is generated, would process the decoded data as part of a useful workflow, and ii) a data transmission function which, if decoded data is generated and/or processed by the barcode-reading application **24**, would make the decoded data available to another local application (e.g., another application on the mobile device **18**) or a remote application (e.g., another application or database on any of the host computer **19**, a local server coupled to the LAN **12**, or a remote server coupled to the Internet **16**.

There may be two sub-embodiments of the licensed operation state **476**. In a first sub-embodiment, all of the functions of the barcode-reading application **24** may be enabled. In a second sub-embodiment, all functions of the barcode-reading application **24** may be enabled except restrictions on the output of useful decoded data may be implemented. The restrictions may be specified in the license key which transitions the barcode-reading application **24** from the disabled state **474** to the licensed operation state **476**. The restrictions may be symbology restrictions, time restrictions, and/or quantity restrictions.

FIG. **21** shows examples of a data structure of a license key in accordance with some embodiments. A first example license key **702** may include data fields (that may be encrypted) which specify the symbologies **708** (for example, symbologies A, B, and C that correspond to a Universal Product Code (UPC), a Quick Response (QR) Code, and a Portable Data File (PDF)-**417**) and a lease term **710**. The lease term **710** may specify a date and time at which the license key **702** expires. In response to receipt of this license key **702** (and decryption of the license key **702** if encrypted) the barcode-reading application **24** may transition to the licensed operation state **476**, decode the specified symbologies **708** when in the licensed operation state **476** (while remaining disabled for decoding other symbologies not specified in the license, for example for a data matrix), and at the end of the lease term **710**, transition back to the disabled state **474** (unless a new license key with an updated lease term **710** is received prior to expiration, which functions to extend the expiration of the lease term).

A second example license key **704** may include data fields (that may be encrypted) which specify the symbologies **712***a-c* (for example, symbologies A, B, and C that correspond to a UPC, a QR Code, and a PDF-**417**), and a licensed quantity of decodes **714***a-c* for each symbology **712***a-c*. The licensed quantity of decodes for a particular symbology, for example the licensed quantity **714***a* for symbology **712***a*, may be unlimited. The licensed quantity of decodes **714***b-c* for symbologies **712***b-c* may be limited to a specified quantity. The entire license key **704** may further include a lease term **716** which may specify a date and time at which the license key **704** expires. In response to receipt of this license key **704** (and decryption of the license key **704** if encrypted) the barcode-reading application **24** may transition to the licensed operation state **476**, and decode the specified symbologies **712***a-c* when in the licensed operation state **476** up to the licensed quantities **714***a-c*. The barcode-reading application **24** may remain disabled for decoding other symbologies not specified in the license (e.g., symbologies other than **712***a-c*), automatically disable each of symbologies **712***b-c* when the total quantity of decodes of each symbology **712***b-c* exceeds the licensed quantity **714***b-c* (unless a new license key increases the quantity), and transition back to the disabled state **474** (unless a new license key with an updated lease term **710** is received prior to expiration, which functions to extend the expiration of the lease term). In this arrangement, the ability to decode symbologies **712***b-c* will expire upon the earlier of: i) reaching the maximum quantity of decodes **714***b-c*, or ii) expiration of the lease term **716**.

A third example license key **706** may include data fields (that may be encrypted) which specify the symbologies **718***a-c* (for example, symbologies A, B, and C that correspond to a UPC, a QR Code, and a PDF-**417**), a license term **720***a-c* for each symbology **718***a-c*, and a licensed quantity **722***a-c* for each symbology **718***a-c*. The license term **720***a-c* may specify a date and time at which the license for that particular symbology **718***a-c* expires. The license term may be perpetual (e.g., license term **720***a-b*) or time limited (e.g., license term **720***c*). The licensed quantity of decodes for a particular symbology may be unlimited (e.g., the licensed quantity **722***a* for symbology **718***a*), or may specify a specific quantity (e.g., the licensed quantity **722***b-c* for symbologies **718***b-c*).

In response to receipt of this license key **706** (and decryption of the license key **706** if encrypted) the barcode-reading application **24** may transition to the licensed operation state **476**, and decode the specified symbologies **718***a-c* when in the licensed operation state **476** up to the licensed quantities **722***a-c* for each symbology and for the duration of the license term **720***a-c* for each symbology. The barcode-reading application **24** may remain disabled for decoding other symbologies not specified in the license (e.g., symbologies other than **718***a-c*), and automatically disable each of symbologies **718***b-c* when the earlier of: i) the expiration of the license term **720***a-c* for each symbology **718***a-c* expires, or ii) the total quantity of decodes of each symbology **718***b-c* exceeds the licensed quantity **722***b-c*, each being subject to extension by a new license key with an increased term duration or an increased quantity.

Each of the license keys may be a data file, specifying the symbologies, the license terms, and the license quantities as depicted in FIG. **21**. The data file may be encrypted utilizing an encryption key (e.g., a private key of a public/private key pair). The encrypted data file may form the license key and may be decrypted by the barcode-reading application **24** utilizing an encryption key (e.g., a public key of the public/private key pair). Other known encryption technologies may also be utilized for securing the delivery of the license key to the barcode-reading application including the license restrictions (e.g., licensed symbologies, license terms, and licensed quantities) within the license key.

FIG. **20**B is a state machine diagram depicting three states of operation in a barcode-reading application **24** in accordance with another embodiment. The first state of operation may be a base state **470**. When in the base state, the barcode-reading application **24** may include barcode-reading capabilities which, although functional and capable of generating useful decoded data, are limited by at least one factor or function (which will be referred to as a demonstration factor) which makes output of decoded data useful for demonstration purposes but not practical for ongoing operation.

The operation of the barcode-reading application **24** in the base state may be a base decoding mode of operation or a demonstration mode of operation. In the base decoding mode of operation, the barcode-reading application **24** may drive the camera of the mobile device **18** to capture an image of a barcode, and apply base decoder functions to the image to identify the barcode symbology. If the barcode symbology is a base symbology, the barcode-reading application **24** may decode the barcode and make the decoded data available for further processing. If the symbology is other than a base symbology, the barcode-reading application **24** may enter the demonstration mode of operation.

In the demonstration mode of operation, the barcode-reading application **24** may apply at least one unlicensed enhanced barcode-reading function to decode the barcode, and perform at least one of: i) outputting an indication of successfully decoding the barcode, or ii) implementing a restriction function. The restriction function may be at least one of: i) a function which scrambles decoded data; ii) a function which restricts the decoded data or scrambled decoded data from the barcode from being made available for further processing by at least one application executing on the mobile device; or iii) a function which restricts the decoded data or the scrambled decoded data from the barcode from being displayed on a display screen of the mobile device.

The at least one demonstration factor may include, but is not limited to: i) a scrambling function which, upon generating decoded data, provides the output in a scrambled or truncated format for purposes of demonstrating decoding capabilities (and decoder performance) but preventing use of the decoded data for further data processing, ii) a time delay function which, upon generating and outputting decoded data (or scrambled decoded data), provides for implementing a time delay before a barcode of the same symbology can again be successfully decoded, iii) an output restriction function which restricts decoded data (or scrambled decoded data) from being made available for further processing by at least one application executing on the mobile device **18**, and iv) an output restriction function which enables outputting decoded data (or scrambled decoded data) to the display screen and prevents the decoded data from being further processed by the mobile device **18** (other than presentation on the display screen) or transmission to a remote application.

The demonstration mode of operation may include an upgrade function. The upgrade function may enable user selection to obtain the license code and upon user selection to obtain the license code, establish the network connection to the licensing server and obtain the license code from the licensing server **21***a*, **21***b*.

The at least one demonstration factor may be applied to selected symbologies or all symbologies. Different demonstration factors may be applied to different symbologies.

The barcode-reading application **24** may transition from the base state **470** to a license key retrieval state **471**. Reading a barcode to which a demonstration factor applies may trigger transition of the barcode-reading application **24** to the license key retrieval state **471**. Alternatively, the barcode-reading application **24** may transition to the license key retrieval state **471** upon user selection of the license key retrieval state **471**.

When in the license key retrieval state **471** the barcode-reading application **24** may connect to a licensing server **21***a*, **21***b* to obtain a license key. After obtaining the license key, the barcode-reading application **24** may transition to a licensed operation state **472** (i.e., an enhanced operation state).

The licensed operation state **472** may enable the barcode-reading application **24** to function without limitations of the at least one demonstration factor such that the barcode-reading application **24** may be capable of capturing an image of a barcode for image processing and decoding, decoding the image of the barcode to generate decoded data, and performing, as applicable: i) a data processing function which, if decoded data is generated, would process the decoded data as part of a useful workflow, and ii) a data transmission function which, if decoded data is generated and/or processed by the barcode-reading application **24**, would make the decoded data available to another local application (e.g., another application on the mobile device **18**) or a remote application (e.g., another application or database on any of the host computer **19**, a local server coupled to the LAN **12**, or a remote server coupled to the Internet **16**), in each case without being impeded by the demonstration factor.

As described with respect to the licensed operation state **476** in FIG. **20**A, there may be two sub-embodiments of the licensed operation state **472**. In a first sub-embodiment, all of the functions of the barcode-reading application **24** may be enabled. In a second sub-embodiment, all functions of the barcode-reading application **24** may be enabled except restrictions on the output of useful decoded data may be implemented. The restrictions may be specified in the license key which transitions the barcode-reading application **24** to the licensed operation state **472**. The restrictions may be symbology restrictions, time restrictions, and/or quantity restrictions.

FIG. **22**A depicts an exemplary operation of a license server **21***a*, **21***b*. Step **370** represents receiving a license key request from the barcode-reading application **24** (or other application) of the mobile device **18**. Receiving the license key request may include authenticating the user of the mobile device **18**. Authenticating the user of the mobile device **18** may include: i) authenticating the individual to which the mobile device is assigned or the individual using the mobile device (or the individual who controls the mobile device), for example utilizing a combination of a user ID and a password or similar schemes for authenticating an individual, and/or ii) authenticating an organization, company, or other group of users to which the mobile device is assigned, for example utilizing a combination of a user ID and a password or other similar schemes for identifying whether the device has been assigned to the organization, company, or group and authenticating the assignment. The user ID may be unique to the device or common for all mobile devices **18** assigned to the organization, company, or group.

Step **372** represents the license server **21***a*, **21***b* checking whether a pre-paid license is available for the mobile device **18**. More specifically, the identity of the individual, organization, company, or other group of users identified during the authentication may be used to look up (e.g., in a license database) licenses available to that individual, organization, company, or other group of users (if any). For a particular individual, organization, company, or other group of users, a certain quantity of licenses may have been pre-purchased.

FIG. **22**C depicts an exemplary database **739** for recording pre-paid licenses that may have been purchased by an individual, organization, company or other group of users. Each such individual, organization, company or other group of users may be identified by a group ID **740**, **750**. Associated with each group ID is one or more license IDs **742**, **752***a*, **752***b*, each of which identifies a license type for the barcode-reading application **24** which may have been purchased in quantities of one or more. Each license type may be, as an example, one of the license types identified by the license keys **702**, **704**, **706** of FIG. **21**.

Each license ID **742**, **752***a*, **752***b* may be associated with identification of: i) the quantity of the license type purchased **744**, **754***a*, **754***b*, ii) the quantity used **746** or the quantity in use **756***a*, **756***b*, and/or iii) the quantity remaining **748**, **758***a*, **758***b* for issuance to mobile devices **18**. It should be appreciated that recording both the quantity used **746** or the quantity in use **756***a*, **756***b* as well as the quantity remaining **748**, **758***a*, **758***b* for issuance to mobile devices is duplicative as either value can be calculated from the quantity purchased **744**, **754***a*, **754***b* and the other value.

Recording the quantity used **746** is useful when licenses are purchased for a single mobile device, and once a license is issued to a particular mobile device it is permanently associated with that mobile device and may not be re-assigned to another mobile device without manual intervention.

Recording the quantity in use **756***a*, **756***b* is useful when the licenses are concurrent-use licenses, and when a license assigned to a mobile device expires it is considered no longer in-use and can be reassigned to another mobile device **18**.

It should also be appreciated that if the quantity of licenses purchased is unlimited **754***a*, it is irrelevant to track in-use licenses **756***a*, **756***b* and remaining licenses **758***a*, **758***b*. When utilizing the concurrent-use licenses, for the in-use licenses **756***b*, the database may include an in-use table **760** which records, for each license **762**, the time **764** at which it expires (e.g., the lease term **710** from FIG. **21**) such that upon expiration (if the expiration is not updated by way of renewal), the license will revert to remaining inventory **758***b* and can be issued to a different mobile device **18**.

It should be appreciated that this licensing scheme enables a mobile device **18** to obtain a license for a specific term, and so long as the mobile device **18** obtains a renewal license prior to expiration, the barcode-reading application **24** can operate under the license even if the mobile device is (periodically) uncoupled from any network and unable to contact the license server **21***a*, **21***b*.

Returning to FIG. **22**A, step **374** represents determining whether a pre-paid license is available. If a prepaid license is available at step **374**, a license key for the pre-paid license is generated at step **376** and the database **739** is updated at step **378**. Updating the database may include recording the license as used **746** or in use **756***b*.

If it is determined at step **374** that a pre-paid license is not available, payment is obtained for a license at step **380**. Step **380** may involve determining the type of license being requested (e.g., as identified by license keys **702**, **704**, **706**), including the licensed symbology(ies) as well as license term(s) and license quantity(ies) for each symbology(ies). In one embodiment, the barcode-reading application **24** may, under the control of the license server **21***a*, **21***b*, generate a menu for user selection of these license parameters (i.e., symbologies, license terms and license quantities) and display on a screen of the mobile device **18** pricing alternatives for desired license parameters.

After payment is obtained, a license key for the license is generated at step **382** and the database **739** is updated at step **384** to reflect a newly purchased license for a user (group ID). If the newly purchased license is a concurrent-use license, updating the database may include recording the license as well as its expiration.

As stated, this licensing scheme enables a mobile device **18** to obtain a license for a specific term, and so long as the mobile device **18** obtains a renewal license prior to expiration, the barcode-reading application **24** can continue operation under the license even if the mobile device **18** is uncoupled from any network and unable to contact the license server **21***a*, **21***b*.

FIG. **22**B depicts an exemplary operation of a license server **21***a*, **21***b* for renewing a license for a mobile device **18** prior to the expiration of the license (e.g., prior to the in-use license **756***b* reverting to a remaining license **758***b*).

Step **770** represents receiving a license key renewal request from the barcode-reading application **24** (or other application) of the mobile device **18**. Receiving the license key renewal request may include authenticating the user of the mobile device **18**. Authenticating the user of the mobile device **18**, as discussed, may include: i) authenticating the individual to which the mobile device is assigned, or the individual using the mobile device (or the individual who controls the mobile device), for example utilizing a combination of a user ID and a password, or similar schemes for authenticating an individual, and/or ii) authenticating an organization, company, or other group of users to which the mobile device is assigned, for example utilizing a combination of a user ID and a password or other similar schemes for identifying whether the device has been assigned to the organization, company, or group and authenticating the assignment. The user ID may be unique to the device or common for all mobile devices **18** assigned to the individual, organization, company, or group. The mobile device **18** (e.g., the barcode-reading application) may communicate to the licensing server i) a unique identification code of the mobile device **18** or ii) a user identification code identifying a controller of the mobile device **18**.

Step **772** represents the license server **21***a*, **21***b* matching the user or the mobile device **18** to the existing in-use license, which may be recorded in an in-use table (for example, the in-use table **760** shown in FIG. **22**C).

Step **774** represents generating, and providing to the mobile device **18**, an update license key which, as depicted by license key **702** of FIG. **21**, may include an updated license term.

Step **776** represents updating the license database such that the expiration date of the license in the in-use table **760** is updated.

Embodiments for a barcode-reading enhancement accessory are disclosed hereafter. As used herein, the terms “attachment” and “accessory” are used synonymously and interchangeably, and may refer to an apparatus attached, coupled, or secured to a mobile device. An attachment for a mobile device may include just a single component that improves the barcode-reading capabilities of the mobile device. Alternatively, an attachment may include multiple components that improve the barcode-reading capabilities of the mobile device. In addition, an attachment for a mobile device may provide additional functionality that is unrelated to improving the barcode-reading capabilities of the mobile device. In some embodiments, the attachment improves the ability of the mobile device to read a barcode utilizing the camera assembly and/or the flash/torch illumination system of the mobile device. In some embodiments, the attachment may include a supplemental camera system and/or one or more supplemental illumination systems which provide barcode-reading capability for the mobile device.

In accordance with some embodiments, a barcode-reading system for a mobile device may include a barcode-reading enhancement accessory secured to the mobile device, which will be explained in detail hereafter, and a barcode-reading application stored in a memory of the mobile device **18**, which is disclosed above. The barcode-reading enhancement accessory may include at least one optic system that is positioned either within a field of illumination of a light source of the mobile device for modifying the field of illumination projected by the light source or within a field of view of a camera of the mobile device for modifying illumination reflected from objects within the field of view of the camera.

As disclosed above, the barcode-reading application **24** may be configured to operate in a base mode or an enhanced mode. In the base mode of operation, the barcode-reading application **24** may be configured to control a network interface of the mobile device **18** to establish a network connection to a licensing server **21**a, **21**b and obtain a license code from the licensing server **21**a, **21**b; subject the license code to a predetermined algorithm and determine at least one operating permission authorized by the license code; and enable an enhanced mode of operation. In the enhanced mode of operation, the barcode-reading application **24** may be configured to implement at least one enhanced barcode-reading function which corresponds to the at least one operating permission authorized by the license code.

The at least one enhanced barcode-reading function may include a function of decoding a barcode symbology that the decoder is restricted from decoding in the base mode of operation. Alternatively or additionally, the at least one enhanced barcode-reading function may include a function of decoding multiple barcodes in sequence at a rate that is faster than a rate at which the barcode-reading application can decode multiple barcodes in sequence in the base mode of operation. Alternatively or additionally, the at least one enhanced barcode-reading function may include a function of decoding a quantity of barcodes of a particular symbology that exceeds a restricted quantity of barcodes of the particular symbology that the barcode-reading application can decode in the base mode of operation.

Alternatively or additionally, the at least one enhanced barcode-reading function may remove a demonstration restriction function under which the barcode-reading application **24** functions in the base mode of operation. The demonstration restriction function may be at least one of: i) a function that scrambles decoded data from a barcode of at least one symbology, ii) a function that restricts the decoded data or scrambled decoded data from a barcode of at least one symbology from being made available for further processing, or iii) a function that restricts the decoded data or the scrambled decoded data from a barcode of at least one symbology from being displayed on a display screen of the mobile device **18**.

Alternatively or additionally, the at least one enhanced barcode-reading function may enable at least one enhanced image processing function that improves an ability to decode an image of a barcode and is not operable when the decoder operates in the base mode of operation.

The base mode of operation may include a base decoding mode of operation and a demonstration mode of operation. In the base decoding mode of operation, the barcode-reading application may be configured to drive the camera assembly to capture an image of a barcode, and apply base decoder functions to the image to identify a barcode symbology. The barcode-reading application **24** may decode the barcode and make decoded data available for further processing if the barcode symbology is a base symbology, and enter the demonstration mode of operation if the barcode symbology is not the base symbology. In the demonstration mode of operation, the barcode-reading application **24** may be configured to: apply at least one enhanced barcode-reading function to decode the barcode, and perform at least one of outputting an indication of successful decoding of the barcode or implementing a restriction function. The restriction function may be at least one of: i) a function that scrambles decoded data, ii) a function that restricts the decoded data or scrambled decoded data from being made available for further processing by at least one application executing on the mobile device **18**, or iii) a function that restricts the decoded data or the scrambled decoded data from being displayed on a display screen of the mobile device **18**.

The barcode-reading application **24** may be configured to perform an upgrade function in the demonstration mode of operation. The upgrade function may enable a user selection to obtain the license code, obtain the license code based on the user selection, establish a network connection to the licensing server **21**a, **21**b, and obtain the license code from the licensing server **21**a, **21**b.

In order to obtain the license code from the licensing server **21**a, **21**b, the barcode-reading application **24** may be configured to communicate to the licensing server **21**a, **21**b one of: i) a unique identification code of the mobile device **18**, or ii) a user identification code identifying a controller of the mobile device **18**.

In accordance with another embodiment, a barcode-reading system for a mobile device may include a barcode-reading enhancement accessory secured to the mobile device **18** and a barcode-reading application **24** stored in a memory of the mobile device **18** and executable by a processor **44** of the mobile device **18**. The barcode-reading enhancement accessory may include at least one optic system that is positioned either within a field of illumination of a white light source of the mobile device **18** for modifying the field of illumination projected by the white light source, or within a field of view of a camera of the mobile device **18** for modifying illumination reflected from objects within the field of view of the camera.

The barcode-reading application **24** may include: i) an image capture function for controlling the white light source and the camera to capture an image of a barcode wherein the image of the barcode may be affected by the at least one optic system, ii) a base decoder function for decoding a barcode in a base mode of operation if an enhanced decoder mode has not been authorized, and iii) an enhanced decoder function for decoding a barcode in an enhanced mode of operation if the enhanced decoder mode has been authorized.

The enhanced decoder function may include a function of decoding a barcode that the barcode-reading application **24** is restricted from decoding in the base mode of operation. Alternatively or additionally, the enhanced decoder function may include a function of decoding multiple barcodes in sequence at a rate that is faster than a restricted rate at which the barcode-reading application **24** can decode a sequence of multiple barcodes when in the base mode of operation. Alternatively or additionally, the enhanced decoder function may include a function of decoding a quantity of barcodes of a particular symbology that exceeds a restricted quantity of barcodes of the particular symbology which the barcode-reading application **24** can decode when in the base mode of operation.

Alternatively or additionally, the enhanced decoder function may remove a demonstration restriction function under which the barcode-reading application **24** functions when in the base mode of operation, thereby making decoded data from a barcode of a particular symbology available for further processing by an application executing on the mobile device **18**. The demonstration restriction function may be at least one of: i) a function which scrambles decoded data from a barcode of at least one particular symbology, ii) a function which restricts the decoded data or scrambled decoded data from a barcode of at least one particular symbology from being made available for further processing by at least one application executing on the mobile device, or iii) a function which restricts the decoded data or the scrambled decoded data from a barcode of at least one particular symbology from being displayed on a display screen of the mobile device **18**.

Alternatively or additionally, the enhanced decoder function may enable at least one enhanced image processing function which improves an ability to decode an image of a barcode and is not operable when the barcode-reading application **24** operates in the base mode of operation. The enhanced decoder mode is enabled by obtaining a license code from a licensing server **21***a*, **21***b*.

The barcode-reading application **24** may be configured to subject the license code to a predetermined algorithm to determine at least one operating permission authorized by the license code. The enhanced decoder function may correspond to the at least one operating permission authorized by the license code.

The barcode-reading application **24** may be configured to obtain the license code from the licensing server **21***a*, **21***b* by communicating to the licensing server one of: i) a unique identification code of the mobile device **18**, or ii) a user identification code identifying a controller of the mobile device **18**.

An attachment for a mobile device **18** may cover a relatively small portion of the mobile device. Alternatively, an attachment for a mobile device may be a protective case that covers a substantial portion of the mobile device. Attachments may be designed for attachment to mobile devices in a wide variety of ways, including but not limited to a corner-positioned attachment, an encapsulating attachment, and a mounting attachment. These attachment modes will be explained in detail below.

FIGS. **4**A and **4**B depict examples of a corner-positioned attachment that covers a relatively small portion of the mobile device **18**. A corner-positioned attachment may cover one or more (but not all) corners of a mobile device.

The corner-positioned attachment **100***a* shown in FIG. **4**A secures to, and covers, a single corner of a mobile device **18**. More specifically, the corner-positioned attachment **100***a* may have an interior back surface **102**, an interior front surface **104**, an interior top surface **106**, and an interior side surface **108**. When installed on the corner of the mobile device **18**: i) the interior back surface **102** faces, and abuts, the back surface **74** of the mobile device **18**; ii) the interior front surface **104** faces, and abuts, the face surface **72** of the mobile device **18**; iii) the interior top surface **106** faces, and abuts, the top edge **78** of the mobile device **18**; and iv) the interior side surface **108** faces, and abuts, the right edge **80** of the mobile device **18**. The distance between the interior back surface **102** and the interior front surface **104** may be sufficiently large to permit the corner-positioned attachment **100***a* to be inserted onto the corner of the mobile device **18** without excessive difficulty, but also small enough that, once installed, the corner-positioned attachment **100***a* will not slide free of the mobile device **18** due to friction fit between: i) the interior back surface **102** and the back surface **74**; and ii) the interior front surface **104** and the face surface **72**. Because the corner-positioned attachment **100***a* covers a single corner of the mobile device **18**, the attachment **100***a* may be installed on the mobile device **18** by sliding the attachment **100***a* along the top edge **78** (e.g. the interior top surface **106** in contact with the top edge **78**) until the interior side surface **108** abuts the right edge **80** of the mobile device. FIG. **4**A shows, as an example, a corner-positioned attachment covering the right top corner of the mobile device **18**. However, the corner-positioned attachment may cover the left top corner or any other corner of the mobile device **18**.

The corner-positioned attachment **100***b* secures to, and covers, two top corners of the mobile device **18** as well as the entire top edge **78**. More specifically, the corner-positioned attachment **100***b* may have an interior back surface **102**, an interior front surface **104**, an interior top surface **106**, and two interior side surfaces **108***a* and **108***b*. When installed on the corner of the mobile device **18**: i) the interior back surface **102** faces, and abuts, the back surface **74** of the mobile device **18**; ii) the interior front surface **104** faces, and abuts, the face surface **72** of the mobile device **18**; iii) the interior top surface **106** faces, and abuts, the top edge **78** of the mobile device **18**; and iv) the interior side surfaces **108***a* and **108***b* face, and abut, the right edge **80** and the left edge **82** of the mobile device **18**, respectively.

The distance between the interior back surface **102** and the interior front surface **104** may be sufficiently large to permit the corner-positioned attachment **100***a* to be inserted onto the corner of the mobile device **18** without excessive difficulty, but also small enough that, once installed, the corner-positioned attachment **100***b* will not slide free of the mobile device **18** due to friction fit between: i) the interior back surface **102** and the back surface **74**, and ii) the interior front surface **104** and the face surface **72**.

Additionally, or alternatively, the distance between the interior side surface **108***a* and the interior side surface **108***b* may be sufficiently large to permit the corner-positioned attachment **100***b* to be inserted onto the corner of the mobile device **18** without excessive difficulty, but also small enough that, once installed, the corner-positioned attachment **100***b* will not slide free of the mobile device **18** due to friction fit between: i) the interior side surface **108***a* and the right edge **80**, and ii) the interior side surface **108***b* and the left edge **82**.

Because the corner-positioned attachment **100***b* covers two corners of the mobile device **18**, the attachment **100***b* may be installed on the mobile device **18** by sliding the attachment **100***b* along each of the left edge **82** and the right edge **80** (e.g. the interior side surface **108***a* in contact with the right edge **80**, the interior side surface **108***b* in contact with the left edge **82**, the interior back surface **102** in contact with the back surface **74**, and the interior front surface **104** in contact with the face surface **72**) until the interior top surface **106** abuts the top edge **78** of the mobile device **18**.

With respect to either attachment **100***a* or **100***b* (or any type of corner-positioned attachment), as an alternative to frictional engagement between the attachment **100***a*, **100***b* and the mobile device **18**, the attachment **100***a*, **100***b* may be secured to the mobile device **18** through the use of various other attachment methods. Such attachment methods include, but are not limited to, mechanical fasteners, adhesives, and the like.

Encapsulating attachments may cover substantially the entirety of the back surface **74** of the mobile device **18** and may further cover substantially the entirety of one or more of the edges **76**, **78**, **80**, and **82** of the mobile device **18**. An encapsulating attachment i) may cover a perimeter edge of the face surface **72** (but does not cover the central portion of the face surface **72**) or ii) may cover substantially the entire face surface **72** but include a transparent central portion, in each case to enable viewing of, and access to, the display screen **66** and touch panel of the mobile device **18**. An encapsulating attachment may further exclude covering interface elements of the mobile device **18**, such as buttons, electrical interfaces, infrared interfaces, and the like.

FIG. **5**A depicts an exemplary encapsulating attachment **110***a* which covers substantially the entire back surface **74** and each of the right edge **80** and the left edge **82** of the mobile device **18** while covering portions of the top edge **78** and the bottom edge **76** near the right edge **80** and left edge **82** (e.g. the corners of the mobile device **18**).

In more detail, the encapsulating attachment **110***a* may include: i) an interior back surface **112** which faces, and abuts, the back surface **74** of the mobile device **18**; ii) interior side surfaces **114***a* and **114***b* which face, and abut, the right edge **80** and the left edge **82** of the mobile device **18**, respectively; iii) an interior top surface **118** which faces, and abuts, the top edge **78** of the mobile device **18** (at the corners); and iv) an interior bottom surface **120** which faces, and abuts, the bottom edge **76** of the mobile device **18** (at the corners). The encapsulating attachment **110***a* may also include an interior side surface **116** which faces, and abuts, at least a portion of the periphery of the face surface **72** of the mobile device **18**.

For installation of the encapsulating attachment **110***a* onto the mobile device **18**, the walls of the encapsulating attachment **110***a* forming the interior side surfaces **114***a* and **114***b* may be sufficiently flexible such that, with pressure, the walls separate as the mobile device **18** is pressed towards the interior back surface **112**, and the portions of the walls which form the interior side surface **116** pass along the right edge **80** and the left edge **82** of the mobile device **18**, and come to rest abutting the periphery of the face surface **72** when the back surface **74** is in contact with the interior back surface **112**.

The encapsulating attachment **110***a*, or more specifically a back side forming the interior back surface **112**, may further include a camera aperture through which the camera assembly (not shown) of the mobile device **18** has the camera field of view **38** to the back surface **74** of the mobile device **18**.

FIG. **5**B depicts another example of an encapsulating attachment **100***b*. The encapsulating attachment **100***b* comprises a top corner-positioned attachment **101***a* (similar to **100***b*) which covers the top two corners of the mobile device **18** and a bottom corner-positioned attachment **101***b* which covers the bottom two corners of mobile device **18**. The two corner-positioned attachments **101***a* and **101***b*, when installed, mate to encapsulate the mobile device **18**. It should be appreciated that the interior front surface of each of the attachments **110***b* (e.g. each of the mating top and bottom corner-positioned attachments) covers a small portion of the periphery of the face surface **72** of the mobile device **18** such that an operator may access the display screen **66** and the touch panel when the mobile device **18** is encapsulated within the attachment **110***b*.

It should be appreciated that the encapsulating attachments **110***a* and **110***b* shown in FIGS. **5**A and **5**B are examples of encapsulating attachments, and the encapsulating attachments may be in any form or type.

Mounted attachments generally are attachments that are secured to one face and/or one edge of a mobile device **18**. Mounted attachments may not cover any corner of the mobile device, and may not encapsulate the mobile device **18**.

FIGS. **6**A and **6**B depict exemplary mounted attachments **122***a*, **122***b* which are secured to the back surface **74** of the mobile device **18**. In FIG. **6**A, the mounted attachment **122***a* may be a barrel shape and include a cylindrical male engagement surface **124** which inserts into a cylindrical recess **126** within the back surface **74** of the mobile device **18** and engages a periphery engagement surface **128** of the cylindrical recess **126** for mounting. The engagement between the engagement surface **124** and the engagement surface **128** may be, for example, by threading, bayonet fitting, or any other mounting structure which may utilize rotational movement between the mounted attachment **122***a* and the mobile device **18** for securing the mounted attachment **122***a* to, and releasing the mounted attachment **122***a* from, the mobile device **18**.

In FIG. **6**B the mounted attachment **122***b* may be a non-cylindrical shape and may be secured into a recess **130** within the back surface **74** of the mobile device **18**. The recess **130** may be of the same shape as the mounted attachment **122***b* and may include an engagement lip or cavity **132** around at least a portion of the periphery of the recess **130** such that engagement clips **134** around the periphery of the mounted attachment **122***b* may secure the mounted attachment **122***b* within the recess **130**.

In addition to the foregoing examples of corner-mounted attachments, encapsulating attachments, and mounted attachments, the barcode-reading enhancement systems and other features embodied in, or related to, attachments as described herein may utilize any (or multiple) attachment structure or means for attaching to the corresponding mobile device including, but not limited to: i) for attachments that cover some portion of the mobile device from two or more sides (e.g. corner-positioned attachments and encapsulating attachments), use of a frictional interface such as a modest interference fit between the interior dimension of the attachment and the exterior dimension of the portion of the mobile device that receives the attachment; ii) for encapsulating attachments, a wide variety of attachment features in known examples of cases, covers, and other protectors for mobile devices; and iii) for attachments that are attached to only one side of the mobile device attachment, features such as threaded fasteners, adhesives, snap-in interfaces, and the like.

The attachments described herein may include target-generating mechanisms as a component of the barcode-reading enhancement system for a mobile device. FIG. **7**A depicts a side cutaway view of an example corner- or edge-mounted attachment (shown as attachment **100***a* covering a single edge of the mobile device **18** as an example) that includes a target-generating structure **136** (i.e., a target-generating mechanism). The target-generating structure **136** projects a targeting beam **138** into a target area **140** (corresponding to a central portion of a field of view **38** of the camera assembly **36** of the mobile device **18**) and may be utilized to facilitate rapid and optimal positioning of a barcode **142** within the camera field of view **38** of the mobile device **18**. The targeting beam **138** is projected at an acute angle **144** with respect to the back surface **74** of the mobile device **18** in a first direction such that the targeting beam **138** intersects the central portion of the camera field of view **38** at a distance from the camera assembly **36** that is useful for barcode reading. The distance useful for barcode reading means that a barcode **142** within the camera field of view **38** would be imaged by the lens assembly **40** with sufficient sharpness (focus) and resolution (size) to enable reading of the barcode **142**. This targeting beam **138** is especially useful when the mobile device **18** does not have a display, or the display is dimmed or turned off to conserve battery power.

FIG. **7**B shows (as a top view, which may be orthogonal to the side view depicted in FIG. **7**A) an example of a target-generating mechanism. The target-generating mechanism may include multiple target-generating structures **136***a* and **136***b*. The target-generating structures **136***a* and **136***b* may project non-parallel targeting beams **138***a* and **138***b* of a distinct illumination pattern, each at an acute angle with respect to the back surface **74** of the mobile device **18** in a second direction orthogonal to the first direction and each of which form a point or a pattern within the target area **140**. The target-generating structures **136***a* and **136***b* may be configured so that (1) at a distance useful for barcode reading (i.e. the optimal distance from the camera assembly **36**), the targeting beams **138***a* and **138***b* converge so that the projected patterns and/or points meet at the center of the camera field of view **38**, and (2) at any distance from the camera assembly **36** other than the optimal distance, the projected patterns and/or points are spaced apart. Thus, when the mobile device **18** is being used to read a barcode **142**, the user may move the mobile device **18** until the projected patterns and/or points meet, indicating that the mobile device **18** is at the optimal distance from the barcode **142** and that the barcode **142** is positioned within the center of the camera field of view **38**.

The target-generating mechanism depicted in FIG. **7**B may include a light source **146***a*, **146***b* and permutations of any of a prism **148***a*, **148***b*; a collimating lens **150***a*, **150***b*; and a pattern-generating surface **152***a*, **152***b* such as an interference pattern-generating element; a diffractive pattern-generating element, such as a holographic element that may include one or more diffractive gratings; or a Fresnel-type pattern-generating element that has been fabricated with the desired targeting beam pattern.

The light source **146***a*, **146***b* may be laser diodes, light-emitting diodes (LEDs), etc. embodied in the attachment or within the mobile device **18**. The targeting beams **138***a*, **138***b* may be generated by shaping the illumination from the white light source of the mobile device by the applicable permutations of the prism **148***a*, **148***b*, a collimating lens **150***a*, **150***b*, and a pattern-generating surface **152***a*, **152***b*.

Although FIGS. **7**A and **7**B depict the target-generating mechanism embodied in a corner- or edge-mounted attachment **100***a*, the target-generating mechanism may be secured to the mobile device **18** by other means including, but not limited to, embodying the target-generating structure **136** into an encapsulating attachment as depicted in FIG. **5**A in alignment with a white light source **84** of the mobile device such that the white light source **84** of the mobile device may be used as the light source **146** of the target-generating structure **136**.

In this application, a "distinct illumination pattern" is an illumination pattern produced by light that is focused to provide relatively crisp lines or other shapes. Thus, the illumination produced by a laser is an example of light that would typically produce a distinct illumination pattern. By contrast, a "diffuse illumination pattern" is an illumination pattern produced by light that is not focused at any particular location, but rather emanating into a broad area. Thus, the illumination produced by a typical light bulb is an example of light that would typically produce a diffuse illumination pattern.

FIGS. **8**A-**8**D illustrate various targeting patterns (distinct illumination patterns) that may be projected by the target-generating structures **136** into the target area **140**. FIG. **8**A shows an example of a targeting pattern **224** that may be projected by the target-generating structure **136**. The targeting pattern **224** includes a circle **226** with a dot **228** in the center. One target-generating structure (**136***a* for example) may generate the circle **226**, while the other target-generating structure (**136***b* for example) may generate the dot **228**. The target-generating structures **136***a*, **136***b* may be configured so that when the mobile device **18** is at an optimal distance from the barcode **142**, the dot **228** is substantially in the center of the circle **226** to form the depicted targeting pattern **224**.

FIG. **8**B shows another example of a targeting pattern **290** that may be projected by the target-generating structures **136**. The targeting pattern **290** includes a cross comprising a horizontal bar **292** and a vertical bar **294**. One target-generating structure (**136***a* for example) may generate the horizontal bar **292**, while the other target-generating structure (**136***b* for example) may generate the vertical bar **294**. The target-generating structures **136***a*, **136***b* may be configured so that when the mobile device **18** is at an optimal distance from the barcode **142**, the horizontal bar **292** and the vertical bar **294** intersect each other within the target area **140** to form the depicted targeting pattern **290**.

FIG. **8**C shows another example of a targeting pattern **296** that may be projected by the target-generating structures **136**. The targeting pattern **296** includes a circle **298** comprising an X pattern **300** within the circle **298**. One target-generating structure (**136***a* for example) may generate the circle **298**, while the other target-generating structure (**136***b* for example) may generate the X pattern **300**. The target-generating structures **136***a*, **136***b* may be configured so that when the mobile device **18** is at an optimal distance from the barcode **142**, the circle **298** and the X pattern **300** may intersect each other to form the depicted targeting pattern **296**.

FIG. **8**D shows another example of a targeting pattern **302** generated by the target-generating structures **136**. The targeting pattern **302** may include an intense illumination in a pattern of one or more quadrilaterals such as a rectangular or square quadrilateral **304** which is/are bounded by a distinct drop in intensity (e.g. a sharp contrast at the edges of the rectangular or square quadrilateral **304**). More specifically, the area around the perimeter of the illuminated rectangular or square quadrilateral **304** may be illuminated (if at all) at an intensity much less than the intensity of illumination within the rectangular or square quadrilateral **304**.

The illuminated rectangular or square quadrilateral **304** may be, for example, illuminated by LEDs projecting (or appearing) blue or white and in the shape of the rectangular or square quadrilateral **304**. The length of the rectangular or square quadrilateral **304** in a first direction (direction **308**) may approximately coincide with the width of the field of view of the camera assembly **36** of the mobile device **18** (or the width of the system field of view if the attachment alters the field of view of the camera assembly **36**); and the length of the rectangular or square quadrilateral **304** in a second direction (direction **306**), orthogonal to the first direction **308**, may approximately coincide with the height of the field of view of the camera assembly **36** of the mobile device **18** (or the height of the system field of view if the attachment alters the field of view of the camera assembly **36**); and, in each case, may be within a central portion of the field of view of the camera assembly **36** of the mobile device **18** as depicted in FIG. **5**A.

Stated another way, the angle at which the illumination diverges from the target-generating structure **136** in the first direction **308** may be approximately the same angle as the field of view of the camera assembly **36** in the first direction **308** (or the same angle as the system field of view if the attachment alters the field of view of the camera assembly **36**). Similarly, the angle at which the illumination diverges from the target-generating structure **136** in the second direction **306** may be approximately the same angle as the field of view of the camera assembly **36** in the second direction **306** (or the same angle as the system field of view if the attachment alters the field of view of the camera assembly **36**). As such, the targeting pattern **302** not only provides the user with an indication of the field of view of the camera assembly **36** (or the system field of view), in both the first direction **308** and the second direction **306**, but the targeting pattern **302** also illuminates substantially all of the field of view in one or both of the first direction and the second direction with an intensity of illumination that does not significantly vary within the targeting pattern **302** but drops significantly at the perimeter of the targeting pattern **302**.

As discussed, the target-generating structure **136** may include its own light source **146***a*, **146***b* (as shown in FIG. 7B) and collimate illumination therefrom to produce the applicable distinct targeting pattern. The illumination source may be of a particular wavelength (e.g. red or blue light) or may be white illumination (broad spectrum) and may include a filter **214***a*, **214***b* (which will be explained in detail with reference to FIG. **9**) to pass only the particular wavelength used to generate the distinct targeting pattern by attenuating other wavelengths.

Alternatively, the target-generating structure **136** may collimate and otherwise shape illumination from the white light source **84** of the mobile device **18** utilizing a collimating lens and/or a pattern-generating surface in both the first direction and the second direction to project the applicable targeting pattern into the target area **140**. In such a case, as shown in FIG. **9**, the target-generating structure **136** may include filters (**214***a*, **214***b*) which pass a narrow band of the visible illumination spectrum, such as red illumination or blue illumination, such that the white illumination (broad spectrum) from the mobile device **18** is filtered and the targeting pattern generated by the combination of the white illumination source and the filter is a specific color, such as blue or red.

The attachments described herein may include supplementary exposure illumination systems as a component of the barcode-reading enhancement system for a mobile device. More specifically, the supplementary exposure illumination systems may include one or more elements which project (or alter the projection of) diffuse illumination into the target area **140** in such a manner that illumination reflected from a barcode **142** and imaged onto the photo sensor **42** produces image characteristics that improve the decode-ability of the image. Image characteristics which improve the decode-ability of the image include: i) increased contrast between illumination reflected from bars (e.g., first modules in a 2D code) versus illumination reflected from spaces (e.g., second modules in a 2D code), and ii) even contrast (e.g., no hot spots, dead zones, or other significant contrast difference) of illumination reflected from bars (or first modules) across the entire barcode **142** and similarly even contrast of illumination reflected from spaces (or second modules) across the entire barcode **142**.

FIG. **9** depicts an example of a mobile device attachment **110** (shown as a cross section of an encapsulating attachment) that includes illumination elements for optimizing illumination for barcode reading. The mobile device **18** includes a white light source **84**. The attachment **110** may include a light pipe **210** that redirects white illumination **212** provided by the white light source **84** of the mobile device **18**. More specifically, utilizing total internal reflection, the light pipe **210** propagates the white illumination **212** in a direction parallel to the back surface **74** of the mobile device **18** towards one or more illumination emanating structures **218***a*, **218***b* which are displaced from the white light source **84** within the plane defined by the back surface **74** of the mobile device **18**.

Each illumination emanating structure **218***a*, **218***b* redirects at least a portion of the white illumination **212** propagating through the light pipe **210** towards a barcode **142** present within the target area **140** as exposure illumination **216***a*, **216***b*. Each emanating structure **218***a*, **218***b* may include any permutation of the prism **148***a*, **148***b* (not shown in FIG. **9** but discussed with respect to FIG. 7B), collimating lens **150***a*, **150***b* (not shown in FIG. **9** but discussed with respect to FIG. 7B), pattern-generating surface **152***a*, **152***b* (not shown in FIG. **9** but discussed with respect to FIG. 7B), and one or more filters **214***a*, **214***b*. The one or more filter(s) **214***a*, **214***b* may include: i) a narrow band filter (e.g. a single-color filter passing a single color of illumination such as red, blue, or another color); ii) a low pass filter passing all color bands below a predetermined wavelength; and/or iii) a high pass filter passing all color bands above a predetermined wavelength. When the one or more filters **214***a*, **214***b* are a narrow band filter (e.g. a single color filter), the exposure illumination **216***a*, **216***b* may be a single color (e.g., red, blue, or another single color). The redirection of illumination by the illumination emanating structures **218***a*, **218***b* may occur by reflection from a chamfered end of the light pipe **210** positioned directly below the illumination emanating structures **218***a*, **218***b*.

In some embodiments, the light pipe **210** and the illumination emanating structures **218***a*, **218***b* may be configured (positioned) such that the exposure illumination **216***a*, **216***b* is offset from the camera's photo sensor **42** (in the plane defined by the back surface **74** of the mobile device **18**) in order to prevent glare. In other words, the exposure illumination **216***a*, **216***b* may be directed toward the target area **140** from locations that are not directly in front of the camera's photo sensor **42**.

FIG. **9** depicts just one example of a supplementary exposure illumination system as a component of the barcode-reading enhancement system for a mobile device. Other supplementary exposure illumination systems may include any of the optic elements (including illumination-generating LEDs) which form a direct bright field illumination system, a diffuse bright field illumination system, and a dark field illumination system as described in U.S. patent application Ser. No. 14/510,341, entitled "DIFFUSE BRIGHT FIELD ILLUMINATION SYSTEM FOR A BARCODE READER," filed on Oct. 9, 2014, and commonly assigned with the present application. The content of the Ser. No. 14/510,341 application is hereby incorporated by reference in its entirety. It should further be appreciated that the supplementary exposure illumination systems utilizing the optic elements of the direct bright field illumination system, the diffuse bright field illumination system, and the dark field illumination system from the Ser. No. 14/510,341 application may further utilize the corresponding illumination sources in conjunction with such optics.

The attachments described herein may include a supplementary optic system as a component of the barcode-reading enhancement system for a mobile device. An "optic system" may be any set of one or more components positioned in the field of view **38** of a camera assembly **36** to modify one or more parameters regarding the light received by the camera, such as the quantity of the light received, the optical pathway along which the light is received, the angular size of the field of view, the depth of field, the focus distance, the f-number, and/or the wavelength(s) of the light received. Thus, an optic system, in various components, may include any of various components such as lenses, filters, mirrors, apertures, and the like. Stated another way, the one or more optical elements within the field of view **38** of the camera assembly **36**, in combination with the lens assembly **40** of the camera, define a barcode-reading optic system (the combination) which provides superior barcode-reading capabilities over the lens assembly **40** alone.

FIGS. **10**A and **10**B depict examples of a mobile device attachment **110** (shown as a mounted attachment) that includes a supplementary lens system that includes permutations of: i) one or more lens(es) **200**; ii) optical filter(s) **204**; and iii) an aperture **202**.

The aperture **202** limits the amount of light that reaches the camera's photo sensor **42** through the camera's lens assembly **40**. More specifically, the aperture **202** may be an aperture within an opaque barrier material which defines the aperture (f-number) of the supplementary lens system and, when part of the barcode-reading optic system, may define the optical aperture (f-number) of the barcode-reading optical system.

The aperture of the barcode-reading optical system, as defined by the aperture **202**, may provide for an increased depth of field (e.g. a system depth of field) over the depth of field provided by the lens assembly **40**. With increased depth of field, an image on the photo sensor **42** sufficiently sharp (focused) for barcode reading may be achieved without the need for autofocusing and therefore the decode response time may be improved because the barcode-reading process does not require a time-consuming autofocusing step.

The one or more lens(es) **200** may alter the field of view **38** of the camera assembly **36** and/or magnification of the camera assembly **36** (e.g. provide a system field of view **207** that is different from the field of view **38** of the camera assembly **36**).

The one or more filter(s) **204** may include: i) a narrow band filter (e.g. a single-color filter passing a single color of illumination such as red, blue, or another color); ii) a low pass filter passing all color bands below a predetermined wavelength; and/or iii) a high pass filter passing all color bands above a predetermined wavelength.

For example, it may be desirable to capture predominantly light of a relatively narrow segment of the visible portion of the electromagnetic spectrum, such as red light with a wavelength of approximately 660 nm. The filter **204** may thus have a colored tint and/or polarization with a narrow wavelength band desired for image capture for effective barcode decoding.

As mentioned previously, the parameters of the camera assembly **36**, such as the angular size of the camera field of view **38**, the range of focus depths, and the depth of field of the camera assembly **36** may not be ideal for barcode capture and/or decoding. Thus, any or all of these parameters may be modified by the optic system of the attachment. Thus, the system field of view **207** may have an angular size that is significantly smaller than the angular size of the camera field of view **38**. This may be because conventional photography often uses a wider lens angle than is needed for capturing barcode images.

The system field of view **207** may provide a system ratio of focal length to entrance pupil diameter that is greater than a camera ratio of focal length to entrance pupil diameter of the unmodified optic system of the camera assembly **36** such that the optic system of the attachment acts to increase the f-stop of the camera lens assembly **40**.

Further, the mobile device **18** and the optic system of the attachment **100**, combined, may have a depth of field (not shown), consisting of the depth along the system optical pathway **205** (e.g., as shown in FIG. **13**) through which an object may remain in focus (to a degree acceptable for barcode capture and/or decoding) on either side of the system focus depth. A relatively large depth of field may advantageously permit barcode capture and/or decoding at a wider range of distances between the mobile device **18** and the barcode to be captured. Thus, the attachment lens may advantageously provide a relatively larger depth of field, particularly at shorter focus depths, than the camera assembly **36**, unaided.

The system field of view **207** may be centered on a system optical pathway, which may be the same as the optical pathway **205** for the camera assembly **36** without the attachment. More specifically, the camera assembly **36** may be designed to capture images centered on an optical pathway **205** perpendicular to the back surface **74** of the mobile device **18**. In certain embodiments this optical pathway is not modified by the attachment; thus, the system optical pathway **205** may be the same as the optical pathway for the camera assembly **36**. In other embodiments, an attachment may provide a different optical pathway for barcode scanning, as will be shown and described with respect to FIGS. **10**C and **10**D.

FIG. **10**C depicts an example of a mobile device attachment **110** (shown as a mounted attachment) that includes a mirror **220** that changes the optical path of illumination (i.e. reflected light) **222** reflected from the barcode to the mobile device **18** from a direction that is generally parallel to the face surface **72** and the back surface **74** of the mobile device **18** to a direction that is generally orthogonal to the lens assembly **40** and the photo sensor **42** of the camera assembly **36** of the mobile device **18**.

The attachment **110** permits a user of the mobile device **18** to attempt to read a barcode **142** positioned within a field of view that is beyond the top edge **78** of the mobile device by aiming the top side (the top edge **78**) of the mobile device **18** at the barcode **142**. The reflected light **222** reflected from the barcode **142** is redirected by the mirror **220** toward the mobile device's focusing lens assembly **40**, which focuses the reflected light **222** onto the photo sensor **42**.

Stated another way, the field of view **38** of the camera assembly **36** would have a center line that is generally orthogonal to the planar back surface **74** of the mobile device **18** (and orthogonal to the planar display on the face surface **72** of the mobile device **18**) and that extends towards a target area **140** from the back surface **74** of the mobile device **18**. The mirror **220** is within such a field of view and folds the field of view such that its center line is parallel to the back surface **74** of the mobile device **18** (and the display on the face surface **72** of the mobile device **18**) and extends towards a target area **140** from the top side of the mobile device **18**.

In the depicted example, the mirror **220** is positioned so that the reflected light **222** is redirected by 90°. Alternatively, the mirror **220** may be positioned so that the reflected light **222** is redirected by a different angle. For example, FIG. **10**D depicts a mirror **220** positioned so that the reflected light is redirected by an angle **221** between 30 and 60 degrees from perpendicular to the back surface **74**.

It should be appreciated that, although not depicted in either FIG. **10**C or **10**D, the attachment **110**, in addition to including the mirror **220** to redirect the reflected light **222**, may further include any permutation of optic components discussed with respect to FIGS. **10**A and **10**B for purposes of altering one or more of the depth of field, the f-number, the angle of the field of view, or the focal plane of the lens assembly **40** of the camera assembly **36**. Such optic components may be located within the region **224***a* of the attachment **110** or the region **224***b* of the attachment **110**.

FIGS. **11**A, **11**B, **12**A, **12**B, **12**C, **12**D, **13**, **14**, and **15** depict additional examples of attachments which may be, or form, a part of the barcode-reading enhancement system for a mobile device. Although each attachment depicted in FIGS. **11**A, **11**B, **12**A, **12**B, **12**C, **12**D, **13**, **14**, and **15** is depicted in one of the general structures described with respect to FIG. **4**A, **4**B, **5**A, **5**B, **6**A, or **6**B, the arrangement of target-generating mechanisms, supplementary illumination systems, and supplementary optic systems described above with respect to FIGS. **7**A, **7**B, **8**A-**8**D, **9**, and **10**A-**10**D may be utilized in any of the general structures.

FIG. **11**A depicts an attachment **20** (shown in partial view) with a target-generating structure **136** which projects a targeting beam **138** from the top edge **78** of the mobile device **18** to the top side of the mobile device **18** to form a targeting pattern **160** within a target area **140** whereas the attachments depicted in FIGS. **7**A and **7**B include a target-generating structure **136** which projects a targeting beam **138** from the back surface **74** of the mobile device **18** and generates the targeting pattern **160** within a target area **140**.

The attachment **20** may further include a structure **230** (with a mirror **220**) as depicted in, and described with respect to, FIG. **10**C or **10**D for redirecting illumination reflected from a barcode in the target area extending from the top edge **78** of the mobile device **18** towards the lens assembly **40** of the camera assembly **36** on the back surface **74** of the mobile device **18**. More specifically, the mirror **220** may be a first mirror within a first chamber **232** within the field of view **38** of the camera assembly **36** (not shown) on the back surface **74** of the mobile device **18**. The first mirror **220** may be positioned at approximately a 45-degree angle to the center line of the field of view **38** of the camera assembly **36** to fold the field of view of the camera by approximately 90 degrees such that the field of view **38** of the camera assembly **36** extends towards the target area **140** extending from the top edge **78** (the top side) of the mobile device **18** instead of from the back surface **74** of the mobile device **18** as described with respect to FIG. **10**A. Alternatively, the first mirror **220** may be positioned at an angle between 30 degrees and 60 degrees from the plane of the back surface **74** of the mobile device.

Further as described with respect to FIGS. **10**A and **10**B (and although not depicted in FIG. **11**A), any permutation of the optics described with respect to FIGS. **10**A and **10**B may be positioned within the first chamber **232** for purposes of altering one or more of the depth of field, the f-number, the angle of the field of view, or the focal plane of the lens assembly **40** of the camera assembly **36**.

The target-generating mechanism may include a second mirror **234**, within a second chamber **236**, generally parallel to the first mirror **220**, but aligned with the white light source **84** on the back surface **74** of the mobile device **18**, and may fold the illumination from the white light source **84** (by the same angle at which the first mirror **220** folds the field of view of the camera assembly **36**) towards the target area **140** extending from the top edge **78** of the mobile device **18**. The first chamber **232** may be separated from the second chamber **236** by an opaque wall or baffle to prevent illumination within the second chamber being incident on the first mirror **220** and reflected by the first mirror **220** onto the lens assembly **40** of the camera assembly **36** and thereby degrading the image quality of an image of a barcode **142** within the target area **140**.

The target-generating mechanism may further include any of the target-generating structures **136** described with respect to FIGS. **7**A and **7**B for forming and projecting the targeting beams **138** of a distinct illumination pattern into the target area **140**. In FIG. **11**A, the target-generating structure **136** is depicted as two collimating lens structures arranged horizontally (within a line generally parallel to the lines formed by the interface of the top edge **78** with each of the face surface **72** and the back surface **74** of the mobile device). Each of the collimating lens structures may project a targeting pattern **160** into the target area **140** which is similar to the targeting pattern **400** depicted in FIG. **7**D. Again, the targeting pattern **400** may be projected into the center of the field of view and the angular size of the targeting pattern with respect to distance from the mobile device **18** may be the same as the angle of the field of view and therefore may serve as both the distinct illumination pattern indicating the field of view and the diffuse illumination (within the field of view) for exposure illumination.

FIG. **11**B depicts an attachment (depicted as a corner- or edge-mounted attachment **100**) which is similar in structure to the encapsulating attachment **110** of FIG. **11**A but with target-generating structures **136** arranged vertically (within a line generally perpendicular to the lines formed by the interface of the top edge **78** with each of the face surface **72** and the back surface **74** of the mobile device). The attachment **100** of FIG. **11**B may further include an exposure illumination structure **238** which may utilize any of the elements described with respect to FIG. **9** or any of the supplementary exposure illumination systems which form the direct bright field illumination system, the diffuse bright field illumination system, and/or the dark field illumination system as described in U.S. patent application Ser. No. 14/510,341.

As stated with respect to FIG. **11**A, the target-generating structure **136** may utilize the second mirror **234** to redirect illumination generated by the white light source **84** into the target-generating structure **136** to form targeting beams **138** or may utilize illumination sources within the attachment **110**. With respect to the embodiment of FIG. **11**B, one of the targeting illumination sources or the exposure illumination source may be the white light source **84** of the mobile device **18** (reflecting from a mirror) and the other of these may be an illumination source within the attachment.

FIGS. **12**A, **12**B, **12**C and **12**D represent an attachment **110** (shown as an encapsulating attachment) with a target-generating structure **136** that may be repositioned and used for any embodiment described herein where the white light source **84** of the mobile device **18** provides illumination for the target-generating structure **136** (which as discussed with respect to FIG. **7**D may also be the exposure illumination system). The repositionable target-generating structure **136** is useful for uses of the mobile device **18** where, in addition to utilizing the white light source **84** and the camera assembly **36** for barcode reading, the white light source **84** and the camera assembly **36** are used for traditional photography.

FIGS. **12**A and **12**B depict the target-generating structure **136** as being pivotally repositionable between: i) a first position **440** as depicted in FIG. **12**A wherein the target-generating structure **136** is positioned in front of the white light source **84** (i.e. an illuminating torch) such that illumination from the white light source **84** is shaped by the target-generating structure **136** into a distinct targeting illumination pattern; and ii) a second position **442** as depicted in FIG. **12**B wherein the target-generating structure **136** is positioned outside of the illumination field of the white light source **84** such that the illumination from the white light source **84** is unmodified by the target-generating structure **136** and can be used for illumination when using the camera assembly **36** of the mobile device **18** to take photographic pictures.

As depicted in FIGS. **12**A and **12**B, the target-generating structure **136** may be secured to the attachment **110** by a flexible band **444** such that the target-generating structure **136** may be pivoted in the direction **446** between position **440** and position **442** by flexure of the flexible band. It is also envisioned that a more traditional hinge/hinge pin structure may also provide for pivoting the target-generating structure **136** between position **440** and position **442** in alternative embodiments.

FIGS. **12**C and **12**D depict the target-generating structure **136** being laterally repositionable between: i) a first position **448** as depicted in FIG. **12**C wherein the target-generating structure **136** is positioned in front of the white light source **84** (i.e. an illuminating torch) such that the illumination from the white light source **84** is shaped by the target-generating structure **136** into a targeting pattern; and ii) a second position **450** as depicted in FIG. **12**D wherein the target-generating structure **136** is positioned outside of the illumination field of the white light source **84** such that the illumination from the white light source **84** is unmodified by the target-generating structure **136** and can be used for illumination when using the camera assembly **36** of the mobile device **18** to take photographic pictures. As depicted in FIGS. **12**C and **12**D, the target-generating structure **136** may be secured to the attachment **110** within a channel **452** such that the target-generating structure **136** may be laterally repositioned in the direction **454** between position **448** and position **450**.

FIG. **13** depicts another exemplary attachment (shown as an encapsulating attachment **100**) for a mobile device **18**. The attachment **100** may have a housing **460** defining an interior cavity **462** of the attachment **100** which is separate from a cavity in which the attachment **100** encapsulates the mobile device **18**.

The cavity **462** within the housing **460** may be divided into one or more chambers separated by an opaque barrier in order to restrict light passage from components in one chamber to components in another. For example, the cavity **462** may have a first chamber **264** and a second chamber **266**. An opaque barrier **268** may separate the first chamber **264** from the second chamber **266** in a manner that prevents light from either of the first chamber **264** and the second chamber **266** from passing directly into the other chamber.

The first chamber **264** may be larger than the second chamber **266**, and may contain components such as a supplementary optic system **271**, attachment control circuitry **270**, and an attachment battery **272**.

The supplementary optic system **271** may be any of the embodiments described with respect to FIGS. **10**A and **10**B. A window **278** within the housing **460** may be in alignment with the supplementary optic system **271** so that illumination reflected from the target area **140** is able to enter the first chamber **264** via the window **278** to reach the supplementary optic system **271** and, after passing through the supplementary optic system **271**, be received and captured by the camera assembly **36** of the mobile device **18**.

In some embodiments, the window **278** may be transparent and function to enclose the first chamber **264**. In other embodiments, the window **278** itself may be a component of the supplementary optic system **271** for modifying one or more of the depth of field, the f-number, the angle of the field of view, or the focal plane of the lens assembly **40** of the camera assembly **36**.

For example, the window **278** may filter illumination reflected from the target area **140** (e.g. pass and/or attenuate certain wavelengths of illumination). The filter characteristics may include any of the filter characteristics described with respect to the filter **214***a*, **214***b* of FIG. **9**.

The second chamber **266** may include one or more of a targeting illumination system **280** and an exposure illumination system **282**. The targeting illumination system **280** may utilize an illumination source **284** and any of the targeting structures **136** described with respect to FIG. **7**A or **7**B to project a targeting beam (not shown) with a distinct illumination pattern (which may be any of the targeting patterns described with respect to FIGS. **8**A, **8**B, **8**C and **8**D) towards the target area **140**.

The exposure illuminating system **282** may utilize an exposure illumination source **286** and the exposure illumination structure described with respect to FIG. **9** or U.S. patent application Ser. No. 14/510,341. The exposure illumination source **286** may include various light sources, including but not limited to lasers, LED's, incandescent lights, fluorescent lights, and the like.

The attachment control circuitry **270** of this embodiment may control each of the targeting illumination systems **280** and the exposure illumination system **282**. The targeting illumination system **280** may be configured to project light into the target area **140** prior to and/or after image capture so as to avoid interfering with the decode-ability of the barcode image. Conversely, the exposure illumination system **282** may project illumination into the target area **140** during image capture.

The targeting illumination system **280** and the exposure illumination system **282** may also be connected to an attachment battery **272**, either independently of the attachment control circuitry **270**, or via the attachment control circuitry **270**. Thus, the targeting illumination system **280** and the exposure illumination system **282** may be controlled by the attachment control circuitry **270** and powered by the attachment battery **272**.

The attachment control circuitry **270** may further include, or be electrically connected to, an attachment communications interface, which may be coupled to the mobile device power/data connector **64** via a link **276***a* and/or the speaker/microphone connector **34** via a link **276***b*.

The housing **460** may further contain a user control **288**, which may be actuated by the user to perform various functions, such as initiating the capture of a barcode. The user control **288** may include any form of user input known in the art, including but not limited to switches, levers, knobs, touch screens, microphones coupled to voice-operation software, and the like. The user control **288** may advantageously take the form of a trigger that can be actuated, for example, with the index finger of the user. In alternative embodiments, the housing **460** may be modified to have a pistol grip or other grip that enhances the ergonomics of the housing **460** and/or facilitates actuation of the user control similar to the housing depicted in FIG. **14**.

FIG. **14** depicts another exemplary attachment (shown as an encapsulating attachment **100** as an example) for a mobile device **18**. The attachment **100** may have a handle **158** which extends downward away from the back surface **74** of the mobile device **18** and is sized and shaped to be gripped by an operator with the operator's thumb and forefinger being positioned at a shoulder **159** where the handle **158** meets a portion of the attachment **100** which is adjacent to the back surface **74** of the mobile device **18**. When held in this manner the face surface **72** of the mobile device is visible to an operator looking downward.

A trigger switch **157** is positioned at the shoulder **159** and is intended to enable the operator to trigger reading of a barcode utilizing the same ergonomics of a typical "gun" type of barcode reader. The trigger switch **157** activates a trigger circuit **161**.

The attachment **100** includes a microphone connector **155** (shown as a speaker/microphone male connector coupled within the speaker/microphone connector **34** of the mobile device **18**).

The trigger circuit **161** includes an oscillator circuit configured to create a potential difference between the ground contact and the microphone contact of the speaker/microphone connector **155** that is detectable by the mobile device **18**. The potential difference may be generated by physical movement of a magnet with respect to a coil with such physical movement being generated by pulling the trigger switch **157**. A combination of springs and spring-activated switches may accentuate the movement of the magnet with respect to the coil and/or break the circuit to ensure that activation of the trigger switch **157** is detectable by the mobile device **18**.

The attachment **100** may also include a structure described with respect to FIG. **10**C or **10**D for purposes of folding the optical path for illumination reflected from the target area **140** so that the field of view of the camera assembly **36** (e.g. the system field of view) is folded from the back surface **74** of the mobile device towards the target area **140** positioned at the top side of the mobile device **18**. The attachment **100** also includes a battery **163** for supplying power to the components in the attachment **100**.

FIG. **15** illustrates a mobile device **18** with an attachment **20** which may include supplementary optic system **271** for image capture and a target-generating structure **136** which utilizes the white light source **84** of the mobile device **18** to generate an intense targeting illumination pattern into the target area.

More particularly, the target-generating structure **136** may comprise a collimating lens **150** which is positioned within, and modifies, the field of illumination **151** of the white light source **84** into the shape of an intense targeting illumination pattern, which may be a pattern depicted in any of FIG. **8**A, **8**B, **8**C or **8**D. The target-generating structure **136** may include a filter **214** which may be a band pass filter or a low pass filter as described with respect to FIG. **19**C for passing a certain color of illumination while attenuating wavelengths other than the certain color.

In a case where the intense targeting illumination pattern is as depicted in FIG. **8**D with diffuse illumination across the field of view, the system illumination field **156** (e.g., illumination as modified by the target-generating structure **136**) may substantially overlap with the system field of view **207**. Thus, with the aid of the target-generating structure **136** the system field of view **207** may be effectively illuminated with diffuse illumination and the borders of the diffuse illumination (as depicted in FIG. **8**D) may enable the user to properly position the mobile device **18** with respect to a barcode in the target area **140**.

In the event the targeting pattern does not provide diffuse illumination across the system field of view **207**, the supplementary optic system **271** may include a high pass filter described with respect to FIG. **19**C such that the illumination of the targeting pattern (as filtered) is attenuated by the high pass filter and does not affect the intensity of the illumination incident on the photo sensor **42**.

FIG. **23** is an exploded view of an exemplary barcode-reading enhancement accessory **2300** configured as an encapsulating attachment. The barcode-reading enhancement accessory **2300** may comprise an outer case **2312** and one or more inner carriages **2314***a*, **2314***b*. FIG. **23** depicts two inner carriages **2314***a*, **2314***b* as an example. However, the accessory **2300** may include just one inner carriage or more than two inner carriages. The accessory **2300** may further include an impact-absorbing cover **2336** positioned over, or molded over, at least a portion of the outer case **2312** to protect a mobile device **18** encased therein.

The outer case **2312** may comprise a cavity **2317** into which each one of the inner carriages **2314***a*, **2314***b* may be inserted. One inner carriage **2314***a*, **2314***b* may be accommodated in the outer case **2312** at one time. The cavity **2317** may be defined by the interior surfaces of the outer case **2312**. More specifically, the cavity **2317** may be defined by a back side interior surface **2320**, a face interior surface **2322** which is generally parallel to the back side interior surface **2320**, a top edge interior surface **2340**, a bottom edge interior surface (not shown in FIG. **23**), which is opposite, and parallel, to the top edge interior surface **2340**, a left edge interior surface **2326**, and a right edge interior surface **2324**, which is opposite, and parallel, to the left edge interior surface **2326**. Each of the top edge interior surface **2340**, the bottom edge interior surface, the left edge interior surface **2326**, and the right edge interior surface **2324** may be generally planar and extend between the back side interior surface **2320** and the face interior surface **2322**, and define a perimeter of each of the back side interior surface **2320** and the face interior surface **2322**. The top edge interior surface **2340** and the bottom edge interior surface may each be orthogonal to each of the left edge interior surface **2326** and the right edge interior surface **2324**. The face interior surface **2322** may include an aperture through which a display screen **43** of a mobile device **18** may be viewed and as such the face interior surface **2322** may be a thin band which extends around the periphery defined by the top edge interior surface **2340**, the bottom edge interior surface, the left edge interior surface **2326**, and the right edge interior surface **2324**.

The outer case **2312** may be open to enable the inner carriage **2314***a*, **2314***b* to be inserted into, and removed from, the outer case **2312**. For example, as shown in FIG. **23**, the outer case **2312** may comprise two mating parts **2312***a*, **2312***b*, which can be secured to each other to form the outer case **2312**. The two mating parts **2312***a*, **2312***b* may be secured to each other, for example, by sliding one mating part **2312***b* in a mating direction **2338** towards the other mating part **2312***a* until the two mating parts **2312***a*, **2312***b* are secured by a latching (fastening or clamping) mechanism. The latching mechanism may be provided on the side walls or a back side surface of the outer case **2312**. Any conventional latching, fastening, or clamping mechanism may be employed to secure the two mating parts **2312***a*, **2312***b*. Similarly the outer case **2312** may be opened by releasing the latching mechanism and sliding the two mating parts **2312***a*, **2312***b* apart.

Alternatively, the two mating parts may be connected together by a hinge at one corner of the outer case **2312** and may be secured at the other corner by a latching mechanism, similar to the embodiment shown in FIGS. **30** and **31**, or may be connected by screws or pins, similar to the embodiment shown in FIG. **32**. Alternatively, the outer case **2312** may be a one-piece component and the combination of the inner carriage **2314***a*, **2314***b* and the mobile device **18** may be simply pushed into the cavity of the outer case **2312**.

Each inner carriage **2314***a*, **2314***b* may include a cavity **2346** to accommodate a mobile device **18** therein. FIG. **23** shows the inner carriage **2314***b* with a mobile device **18** accommodated therein. Each inner carriage **2314***a*, **2314***b* may accommodate a particular size or model of a mobile device **18** for which each inner carriage **2314***a*, **2314***b* is designed.

The cavity **2346** of the inner carriage **2314***a*, **2314***b* may be defined by the interior surfaces of the inner carriage **2314***a*, **2314***b*. For example, the cavity **2346** of the inner carriage **2314***a*, **2314***b* may be defined by a back side interior surface **2350**, a face interior surface **2352** (if present), which is generally parallel to the back side interior surface **2350**, and i) a left edge interior surface **2354** and a right edge interior surface **2356**, which is opposite, and parallel, to the left edge interior surface **2354**, and/or ii) a top edge interior surface (not depicted in FIG. **23**) and a bottom edge interior surface (not depicted in FIG. **23**). FIG. **23** shows the inner carriage **2314***a*, **2314***b* having a left edge interior surface **2354** and a right edge interior surface **2356**. However, it should be noted that the inner carriage **2314***a*, **2314***b* may have all four edge interior surfaces or may only have a top edge interior surface and a bottom edge interior surface.

Each of the top edge interior surface (if present), the bottom edge interior surface (if present), the left edge interior surface **2354** (if present), and the right edge interior surface **2356** (if present) may be generally planar and extend between the back side interior surface **2350** (and the face interior surface **2352** if present), and define a perimeter of each of the back side interior surface **2350** and the face interior surface **2352**. The top edge interior surface (if present) and the bottom edge interior surface (if present) may each be orthogonal to each of the left edge interior surface **2354** and the right edge interior surface **2356**. The face interior surface **2352** (if present) may include an aperture (or otherwise be open) through which a display screen **43** of a mobile device **18** may be viewed and as such the face interior surface may be a thin band which extends around along each of the left edge interior surface **2354** and right edge interior surface **2356**.

At least a portion of the interior surface of the inner carriage **2314***a*, **2314***b* conforms to at least a portion of an exterior surface **2348** of a mobile device **18** for which the inner carriage **2314***a*, **2314***b* is designed. Each inner carriage **2314***a*, **2314***b* may have dimensions of its interior surface different from other inner carriages **2314***a*, **2314***b*. Each inner carriage **2314***a*, **2314***b* has its interior dimensions sized to fit the exterior dimensions of a mobile device **18** of a different size or model such that a mobile device **18** of a different size or model may be accommodated in the outer case **2312** using a corresponding inner carriage **2314***a*, **2314***b* designed for the mobile device **18**.

At least a portion of the exterior surface **2344** of the inner carriage **2314***a*, **2314***b* conforms to at least a portion of one or more of the interior surfaces of the outer case **2312**. The inner carriage **2314***a*, **2314***b*, when inserted into the cavity **2317**, may be secured in position without room for movement in at least one of the directions: i) between the top edge interior surface **2340** and the bottom edge interior surface; ii) between the left edge interior surface **2326** and the right edge interior surface **2324**; and iii) between the back side interior surface **2320** and the face interior surface **2322**. In directions where the fit between portions of the exterior surface **2344** of the inner carriage **2314***a*, **2314***b* and the interior surfaces of the outer case **2312** may not fully secure the inner carriage **2314***a*, **2314***b* from movement, when a mobile device **18** is inserted into the inner carriage **2314***a*, **2314***b* and the combination is inserted into the cavity **2317**, the combined exterior dimensions of the inner carriage **2314***a*, **2314***b* and the mobile device **18** may secure the inner carriage **2314***a*, **2314***b* from movement in at least one of the directions: i) between the top edge interior surface **2340** and the bottom edge interior surface; ii) between the left edge interior surface **2326** and the right edge interior surface **2324**; and iii) between the back side interior surface **2320** and the face interior surface **2322**.

The mobile device **18** is accommodated within the inner carriage **2314***a*, **2314***b* and the combination of the inner carriage **2314***a*, **2314***b* and the mobile device **18** is inserted into the cavity **2317** of the outer case **2312**. The combined exterior dimensions of the inner carriage **2314***a*, **2314***b* and the mobile device **18** may fit the interior dimension of the cavity **2317** so that the combination of the inner carriage **2314***a*, **2314***b* and the mobile device **18** is secured from movement in all of directions: i) between the top edge interior surface **2340** and the bottom edge interior surface; ii) between the left edge interior surface **2326** and the right edge interior surface **2324**; and iii) between the back side interior surface **2320** and the face interior surface **2322**. When so secured, the position at which the mobile device **18** is positioned with respect to the outer case **2312** is referenced to as the "operating position."

The accessory **2300** also includes an optic system **2370**. The optic system **2370** is secured to the outer case **2312** and is configured to fold an optical path (extending to the back side of the mobile device **18** to a direction extending into the area beyond the top edge of the mobile device **18**) of at least one of a field of illumination of a light source of the mobile device **18** or a field of view of a camera of the mobile device **18** when the mobile device **18** is accommodated in the outer case **2312** using the inner carriage **2314***a*, **2314***b*.

When the mobile device **18** is in the operating position, the optic system **2370** of the accessory **2300** may be within at least one of the field of illumination of the white light source of the mobile device **18** and/or the field of view of the camera of the mobile device **18**. The dimensions of the inner carriage **2314***a*, **2314***b* are selected so that the mobile device **18** is positioned within the cavity **2317** of the outer case **2312** so that the optic system **2370** is within at least one of the field of illumination of the white light source of the mobile device **18** and/or the field of view of the camera of the mobile device **18**.

The optic system **2370** may include, or be configured similarly to, any of the other optic systems, or components, thereof, including those described with respect to FIGS. **10**A, **10**B, **10**C, **10**D, **11**A, **11**B, **12**A, **12**B, **12**C, **12**D, **13**, **14**, and **15**.

The outer case **2312** may include a connector **2330** on the interior surface (e.g., on the bottom interior surface of the outer case **2312**) for connection to the mating connector **2332** of the mobile device **18** when the mobile device is secured in the outer case **2312**. The outer case **2312** may include a trigger switch (not shown) for an operator to trigger capturing of a barcode with the mobile device **18**. A trigger circuit included in the outer case **2312** may send a trigger signal to the mobile device via the connector **2330** as described herein.

When the mobile device **18** is in the operating position, the connector **2330** within the interior of the outer case **2312** is aligned both vertically and horizontally with the mating connector **2332** on the mobile device **18**. The dimensions and shape of the inner carriage **2314***a*, **2314***b* are selected so that when the combination of the inner carriage **2314***a*, **2314***b* and the mobile device **18** is secured in the outer case **2312**, the connector **2330** in the outer case **2312** is aligned both vertically and horizontally with the mating connector **2332** on the mobile device **18**. FIGS. **24**A and **24**B are sectional views of exemplary inner carriages **2314***a*, **2314***b* with a mobile device **18** inserted therein. The dimensions including the thickness **2334***a*, **2334***b* of the back panel **2336***a*, **2336***b* of each inner carriage **2314***a*, **2314***b* and the shape of the internal surfaces of each inner carriage **2314***a*, **2314***b* are selected for a particular model or size of a mobile device **18***a*, **18***b*, respectively, so that when the combination of the mobile device **18***a*, **18***b* and the corresponding inner carriage **2314***a*, **2314***b* is inserted into the outer case **2312**, the connector **2330** in the outer case **2312** and the mating connector **2332** on the mobile device **18** are aligned.

Each inner carriage **2314***a*, **2314***b* may include one or more apertures **2360***a*, **2360***b* within one or more of its walls to expose control buttons or switches on the mobile device **18** when the mobile device **18** is inserted into the inner carriage **2314***a*, **2314***b*. Each inner carriage **2314***a*, **2314***b* is designed for a mobile device **18** of a particular model or size so that each aperture **2360***a*, **2360***b* is positioned for the control buttons or switches on the mobile device **18** of a particular model or size for which the inner carriage **2314***a*, **2314***b* is designed. Alternatively, instead of the aperture(s) **2360***a*, **2360***b*, a flexible button or switch may be formed in the corresponding position in the wall(s) of the inner carriage **2314***a*, **2314***b* so that the control buttons or switches on the mobile device **18** may be operated through the flexible button or switch formed in the wall(s) of the inner carriage **2314***a*, **2314***b*.

The outer case **2312** may include one or more apertures **2362** in one or more of its walls in a location(s) corresponding to the aperture **2360***a*, **2360***b* in the inner carriage **2314***a*, **2314***b*. The aperture(s) **2362** may include a superset of the apertures **2360***a*, **2360***b* of some or all of inner carriages **2314***a*, **2314***b* that the outer case **2312** may accommodate. Stated another way, since the outer case **2312** may accommodate a number of different inner carriages **2314***a*, **2314***b* designed for different mobile devices, an aperture **2362** may be formed within the wall(s) of the outer case **2312** to cover apertures **2360***a*, **2360***b* of some or all of the inner carriages **2314***a*, **2314***b* that may be inserted into the outer case **2312**. As such, the control buttons or switches of each mobile device **18** may be accessed through the aperture **2360***a*, **2360***b* in the inner carriage **2314***a*, **2314***b* and the aperture **2362** in the outer case **2312**. The aperture **2362** in the outer case **2312** may be larger than the aperture **2360***a*, **2360***b* in the inner carriage **2314***a*, **2314***b*. Alternatively, instead of aperture(s) **2362**, a flexible button(s) or switch(es) may be formed in the wall(s) of the outer case **2312** so that the control buttons or switches on the mobile device may be operated through the flexible buttons or switches.

FIG. **25** shows an exemplary outer case **2512** and exemplary inner carriages **2514***a*-**2514***c* with structural components similar to those described with respect to FIG. **23**. The outer case **2512** may comprise two mating parts **2512***a*, **2512***b* that are combined to form the outer case **2512**. For example, one of the mating parts **2512***a*, **2512***b* may include a tongue(s) **2513** and the other may include a groove (not shown) for connecting the two mating parts **2512***a*, **2512***b*. Alternatively, any other connecting and locking mechanism may be employed to combine the two mating parts **2512***a*, **2512***b*.

Each inner carriage **2514***a*-**2514***c* is designed for accommodating a mobile device **18***a*-**18***c* of a different model or size. Each combination of an inner carriage **2514***a*-**2514***c* and a mobile device **18***a*-**18***c* is inserted into the cavity of the outer case **2512**. The outer case **2512** includes a connector **2530** for connecting with a mating connector on the mobile device **18***a*-**18***c*.

A handle **2540** may be attached to, or be a part of, the outer case **2512**, similar to the embodiment shown in FIG. **14**. The handle **2540** may be attachable and detachable. The handle **2540** extends downward away from the back exterior surface of the outer case **2512** and is sized and shaped to be gripped by an operator with the operator's hand. When held by the operator, the face surface of the mobile device **18***a*-**18***c* is visible to the operator looking downward. The handle **2540** may have a trigger switch to enable the operator to initiate reading of a barcode with the mobile device **18***a*-**18***c*. The trigger switch activates a trigger circuit in the handle **2540** which sends a trigger signal to the mobile device **18** via the connector **2530**. The handle **2540** may include a battery for supplying power to the components in the handle **2540** and a charging power to the mobile device **18**.

An optic system **2570** may be attached to, or be a part of, the outer case **2512**. When the mobile device **18** is inserted into the outer case **2512**, the optic system **2570**, similar to the attachment **110** disclosed with respect to FIGS. **10**C and **10**D, may fold the optical path of the field of illumination of the light source of the mobile device **18** and/or the field of view of the camera of the mobile device **18** such that the field of illumination of the light source or the field of view of the camera is folded from the back side of the mobile device **18** towards the target area positioned at the top side of the mobile device **18**.

The optic system **2570** may include, or be configured similarly to, any of the other optic systems, or components, thereof, including those described with respect to FIGS. **10**A, **10**B, **10**C, **10**D, **11**A, **11**B, **12**A, **12**B, **12**C, **12**D, **13**, **14**, and **15**.

FIG. **26** shows an exemplary barcode-reading enhancement accessory **2600***a*, **2600***b*, **2600***c* configured as an encapsulating attachment in accordance with another embodiment. FIG. **27** shows the barcode-reading enhancement accessory of FIG. **26** with a mobile device encased into the cavity of the case. FIG. **28** shows the combined state of the case and the handle assembly of the barcode-reading enhancement accessory of FIG. **26**.

A barcode-reading enhancement accessory **2600***a*, **2600***b*, **2600***c* may comprise a handle assembly **2601***a*, **2601***b*, **2601***c* and a case **2604***a*, **2604***b*, **2604***c*. Each case **2604***a*, **2604***b*, **2604***c* is configured for encasing a mobile device **18***a*, **18***b*, **18***c* of a different model or size. The interior and/or exterior dimensions of each case **2604***a*, **2604***b*, **2604***c* is designed differently for accommodating a particular model or size of a mobile device **18***a*, **18***b*, **18***c*. The handle assembly may be generic to all or some of the cases **2604***a*, **2604***b*, **2604***c* so that the same handle assembly may be used with multiple cases **2604***a*, **2604***b*, **2604***c*. Alternatively, each handle assembly **2601***a*, **2601***b*, **2601***c* may be designed for a particular mobile device and may be used with a corresponding case designed for the particular mobile device.

The case **2604***a*, **2604***b*, **2604***c* may comprise a cavity **2618***a*, **2618***b*, **2618***c* into which a mobile device **18***a*, **18***b*, **18***c* is inserted. The cavity **2618***a*, **2618***b*, **2618***c* may be defined by interior surfaces comprising a back side interior surface **2620***a*, **2620***b*, **2620***c*, a face interior surface **2622***a*, **2622***b*, **2622***c*, which is generally parallel to the back side interior surface **2620***a*, **2620***b*, **2620***c*, a top edge interior surface **2640***a*, **2640***b*, **2640***c*, a left edge interior surface **2626***a*, **2626***b*, **2626***c*, and a right edge interior surface **2624***a*, **2624***b*, **2624***c*, which is opposite, and parallel, to the left edge interior surface **2626***a*, **2626***b*, **2626***c*.

The case (e.g., case **2604***a*) may also include a bottom edge interior surface **2641***a*, which is opposite, and parallel, to the top edge interior surface **2640***a*. The case (e.g., case **2604***b*, **2604***c*) may not have the bottom edge interior surface. In this case, a docking surface **2668***b*, **2668***c* of the handle assembly **2601***b*, **2601***c* closes the cavity **2618***b*, **2618***c*.

Each of the top edge interior surface **2640***a*, **2640***b*, **2640***c*, the bottom edge interior surface **2641***a* (or the docking surface **2668***a*, **2668***b*, **2668***c*), the left edge interior surface **2626***a*, **2626***b*, **2626***c*, and the right edge interior surface **2624***a*, **2624***b*, **2624***c* may be generally planar and extend between the back side interior surface **2620***a*, **2620***b*, **2620***c* and the face interior surface **2622***a*, **2622***b*, **2622***c*, and define a perimeter (perimeter edges) of each of the back side interior surface **2620***a*, **2620***b*, **2620***c* and the face interior surface **2622***a*, **2622***b*, **2622***c*. The top edge interior surface **2640***a*, **2640***b*, **2640***c* and the bottom edge interior surface **2641***a* (or the docking surface **2668***a*, **2668***b*, **2668***c*) may each be orthogonal to each of the left edge interior surface **2626***a*, **2626***b*, **2626***c* and the right edge interior surface **2624***a*, **2624***b*, **2624***c*.

The back side interior surface **2620***a*, **2620***b*, **2620***c* and the bottom edge interior surface **2641***a* may each include apertures **2662***a*, **2662***b*, **2662***c* and **2664***a*, respectively. The lack of the bottom edge interior surface in cases **2604***b* and **2604***c* forms apertures **2664***b* and **2664***c*.

The handle assembly **2601***a*, **2601***b*, **2601***c* may include a handle **2602***a*, **2602***b*, **2602***c* and a platform **2603***a*, **2603***b*, **2603***c*. The platform **2603***a*, **2603***b*, **2603***c* includes a platform surface **2666***a*, **2666***b*, **2666***c* and a docking surface **2668***a*, **2668***b*, **2668***c*. When the case **2604***a*, **2604***b*, **2604***c* is coupled to the handle assembly **2601***a*, **2601***b*, **2601***c*, the platform surface **2666***a*, **2666***b*, **2666***c* may: i) be flush (alternatively may not be flush) with the back side interior surface **2620***a*, **2620***b*, and **2620***c*, and ii) fill (or substantially fill) the aperture **2662***a*, **2662***b*, **2662***c*. Similarly the docking surface **2668***a*, **2668***b*, **2668***c* may: i) be flush (alternatively may not be flush) with the bottom edge interior surface **2641***a*, and fill (or substantially fill) the aperture **2664***a*, **2664***b*, **2664***c* thereby completing the partial bottom edge interior surface **2641***a* of the case **2604***a* or becoming the entire bottom edge interior surface of the case **2604***b*, **2604***c*.

As shown in FIG. **28**, the case **2604***a*, **2604***b*, **2604***c* (with the mobile device **18***a*, **18***b*, **18***c* encased in it) is coupled to the handle assembly **2601***a*, **2601***b*, **2601***c* before using as a barcode reading device. For coupling the case **2604***a*, **2604***b*, **2604***c* to the handle assembly **2601***a*, **2601***b*, **2601***c*, a coupling structure may be provided in the case **2604***a*, **2604***b*, **2604***c* and the handle assembly **2601***a*, **2601***b*, **2601***c*. For example, a tongue (or a groove) may be formed along the left and right edges of the platform surface **2666***a*, **2666***b*, **2666***c* and a groove (or a tongue) may be formed along the left and right edges of the aperture **2662***a*, **2662***b*, **2662***c* of the back side interior surface of the case **2604***a*, **2604***b*, **2604***c* so that the case **2604***a*, **2604***b*, **2604***c* may be coupled to the handle assembly **2601***a*, **2601***b*, **2601***c* by sliding the tongue along the groove. Alternatively or additionally, a ridge and a rail may be formed along the left and right edges of the platform surface **2666***a*, **2666***b*, **2666***c* and the left and right edges of the aperture **2662***a*, **2662***b*, **2662***c*. The ridge/rail combination may provide additional strength for securing the case **2604***a*, **2604***b*, **2604***c* to the handle assembly **2601***a*, **2601***b*, **2601***c* and provide greater strength against torsional forces in the direction **2692** shown in FIG. **29** than if the case **2604***a*, **2604***b*, **2604***c* is simply mounted to the handle assembly **2601***a*, **2601***b*, **2601***c* by a mechanical structure on its bottom edge.

The face interior surface **2622***a*, **2622***b*, **2622***c* may also include an aperture through which a display screen **43** of a mobile device **18***a*, **18***b*, **18***c* (as shown in FIG. **27**) may be viewed and as such the face interior surface **2622***a*, **2622***b*, **2622***c* may be a thin band which extends around the periphery defined by the top edge interior surface **2640***a*, **2640***b*, **2640***c*, the bottom edge interior surface **2641***a* (or the docking surface **2668***a*, **2668***b*, **2668***c*), the left edge interior surface **2626***a*, **2626***b*, **2626***c*, and the right edge interior surface **2624***a*, **2624***b*, **2624***c*.

The handle assembly **2601***a*, **2601***b*, **2601***c* and the case **2604***a*, **2604***b*, **2604***c* are separable as depicted in both FIGS. **26** and **27** to enable the mobile device **18***a*, **18***b*, **18***c* to be inserted into, and removed from, the case **2604***a*, **2604***b*, **2604***c*. The handle assembly **2601***a*, **2601***b*, **2601***c* and the case **2604***a*, **2604***b*, **2604***c* may be coupled to each other by sliding the case **2604***a*, **2604***b*, **2604***c* towards the docking surface **2668***a*, **2668***b*, **2668***c* of the handle assembly **2601***a*, **2601***b*, **2601***c* (while the bottom edge interior surface **2620***a*, **2620***b*, **2620***c* is flush with the platform surface **2666***a*, **2666***b*, **2666***c*) and engaging a latching mechanism (not shown). Any conventional latching, fastening, or clamping mechanism may be used to secure the case **2604***a*, **2604***b*, **2604***c* to the handle assembly **2601***a*, **2601***b*, **2601***c*.

At least a portion of the interior surfaces (shown in FIG. **26**) of the case **2604***a*, **2604***b*, **2604***c* (including the docking surface **2668***a*, **2668***b*, **2668***c* of the handle assembly **2601***a*, **2601***b*, **2601***c*) conform to at least a portion of an exterior surface of the mobile device **18***a*, **18***b*, **18***b* for which the case **2604***a*, **2604***b*, **2604***c* is configured. Each case **2604***a*, **2604***b*, **2604***c* may have different dimensions of its interior surfaces to fit a mobile device **18***a*, **18***b*, **18***c* of a different model or size. More specifically, each case **2604***a*, **2604***b*, **2604***c* may comprise interior surfaces into which a particular model or size of a mobile device **18***a*, **18***b*, **18***c* will securely fit. For example, case **2604***a* may be configured to fit the Apple iPhone 6 Plus®, case **2604***b* may be configured to fit the Apple iPhone 6®, and case **2604***c* may be configured to fit the Apple iPhone 5/5s®.

When the case **2604***a*, **2604***b*, **2604***c* carrying a mobile device **18***a*, **18***b*, **18***c* is coupled to the handle assembly **2601***a*, **2601***b*, **2601***c*, the position of the mobile device **18***a*, **18***b*, **18***c* with respect to the accessory **2600***a*, **2600***b*, **2600***c* is referred to as the "operating position," which is depicted in FIG. **28**.

The accessory **2600***a*, **2600***b*, **2600***c* may include an optic system **2670***a*, **2670***b*, **2670***c*. The optic system **2670***a*, **2670***b*, **2670***c* is secured to the case **2604***a*, **2604***b*, **2604***c* and is configured to fold an optical path of at least one of a field of illumination of a light source of the mobile device **18***a*, **18***b*, **18***c* or a field of view of a camera of the mobile device **18***a*, **18***b*, **18***c* when the mobile device **18***a*, **18***b*, **18***c* is accommodated in the case **2604***a*, **2604***b*, **2604***c*.

When the mobile device **18***a*, **18***b*, **18***c* is in the operating position, the optic system **2670***a*, **2670***b*, **2670***c* of the accessory **2600***a*, **2600***b*, **2600***c* may be within at least one of the field of illumination of the white light source of the mobile device **18***a*, **18***b*, **18***c* and/or the field of view of the camera of the mobile device **18***a*, **18***b*, **18***c*. The dimensions of the case **2604***a*, **2604***b*, **2604***c* are selected so that the mobile device **18***a*, **18***b*, **18***c* is positioned within the cavity **2618***a*, **2618***b*, **2618***c* of the case **2604***a*, **2604***b*, **2604***c* so that the optic system **2670***a*, **2670***b*, **2670***c* is within at least one of the field of illumination of the white light source of the mobile device **18***a*, **18***b*, **18***c* and/or the field of view of the camera of the mobile device **18***a*, **18***b*, **18***c*.

In all embodiments, the operating system **48** or barcode reading application may process and decode an image captured by the camera of the mobile device as such image is modified by the optic system, including optic systems **2370**, **2570** and **2670**.

A connector **2672***a*, **2672***b*, **2672***c* (e.g., Apple Lightning Connector®) may be provided on the docking surface **2668***a*, **2668***b*, **2668***c* of the handle assembly for connection to the mating connector **2632***a*, **2632***b*, **2632***c* of the mobile device **18**a, **18**b, **18**c when the combined mobile device and case is coupled to the handle assembly **2601**a, **2601**b, **2601**c. When the mobile device **18**a, **18**b, **18**c is in the operating position, the connector **2672**a, **2672**b, **2672**c on the handle assembly is aligned both vertically and horizontally with the mating connector **2632**a, **2632**b, **2632**c on the mobile device **18**a, **18**b, **18**c. The dimensions and shape of the case **2604**a, **2604**b, **2604**c are selected so that when the combination of the case and the mobile device is coupled to the handle assembly **2601**a, **2601**b, **2601**c, the connector **2672**a, **2672**b, **2672**c on the handle assembly is aligned both vertically and horizontally with the mating connector **2632**a, **2632**b, **2632**c on the mobile device **18**a, **18**b, **18**c.

Typically the mating connector **2632**a, **2632**b, **2632**c on the mobile device **18**a, **18**b, **18**c will be in the center (between the left and right sides when the mobile device **18**a, **18**b, **18**c is viewed in a portrait mode) of the mobile device **18**a, **18**b, **18**c on its bottom surface. There are certain scenarios where all of the mobile devices **18**a, **18**b, **18**c for which the cases **2604**a, **2604**b, **2604**c are designed may have the mating connector **2632**a, **2632**b, **2632**c positioned at the same distance from the back side exterior surface of the mobile device **18**a, **18**b, **18**c. In these scenarios, that distance can be used for the distance between the platform surface **2666**a, **2666**b, **2666**c and the connector **2672**a, **2672**b, **2672**c of the handle assembly **2601**a, **2601**b, **2601**c and the back side interior surface **2620**a, **2620**b, **2620**c of each case **2604**a, **2604**b, **2604**c may be flush with the platform surface **2666**a, **2666**b, **2666**c.

However, there may be other cases where the distance between the mating connector **2632**a, **2632**b, **2632**c on a mobile device **18**a, **18**b, **18**c and the mobile device's back side exterior surface varies among the mobile devices **18**a, **18**b, **18**c for which cases are designed. In these cases, the back side interior surface **2620**a, **2620**b, **2620**c of the case **2604**a, **2604**b, **2604**c may not be flush with the platform surface **2666**a, **2666**b, **2666**c and the mobile device **18**a, **18**b, **18**c should be raised above the platform surface **2666**a, **2666**b, **2666**c to align the mating connector **2632**a, **2632**b, **2632**c of the mobile device **18**a, **18**b, **18**c to the connector **2672**a, **2672**b, **2672**c on the docking surface **2668**a, **2668**b, **2668**c. For example, as shown in the third example (case **2604**c and handle assembly **2601**c) in FIG. **26**, a tongue **2665** may be provided in the back side interior surface **2620**c of the case and a matching slot **2663** may be formed in the platform surface **2666**c of the handle assembly **2601**c. The thickness of the tongue **2665** can vary to raise the mobile device **18**c above the platform surface **2666**c to ensure alignment of the connector **2672**c on the docking surface **2668**c with the mating connector **2632**c on the mobile device **18**c.

Each case **2604**a, **2604**b, **2604**c may include one or more apertures **2674**a, **2674**b, **2674**c, **2674**d within one or more of its walls to expose control buttons or switches on the mobile device **18**a, **18**b, **18**c when the mobile device **18**a, **18**b, **18**c is inserted into the case **2604**a, **2604**b, **2604**c. Each case **2604**a, **2604**b, **2604**c is designed for a mobile device **18**a, **18**b, **18**c of a particular model or size so that each aperture **2674**a, **2674**b, **2674**c, **2674**d is positioned for the control buttons or switches on the corresponding mobile device **18**a, **18**b, **18**c. Alternatively, instead of the aperture(s), a flexible button or switch may be formed in the corresponding position in the wall(s) of the case **2604**a, **2604**b, **2604**c so that the control buttons or switches on the mobile device **18**a, **18**b, **18**c may be operated through the flexible button or switch formed in the wall(s) of the case **2604**a, **2604**b, **2604**c.

FIG. **29** is a cutaway view of an accessory **2600** with the handle assembly **2601** assembled with a case **2604** to encase a mobile device **18**. The handle assembly **2601** includes a handle **2602** extending downward away from the platform **2603**. The handle **2602** is sized and shaped to be gripped by an operator with the operator's thumb and forefinger being positioned at a shoulder **2678** where the handle **2602** meets the platform **2603**. When held in this manner the display screen **43** of the mobile device **18** is visible to an operator looking downward.

A trigger switch **2680** is positioned at the shoulder **2678** and is intended to enable the operator to trigger reading of a barcode utilizing the same ergonomics of a typical "gun" type of barcode reader. The trigger switch **2680** activates a trigger or barcode rendering circuit **2682** in the handle assembly **2601**.

The handle assembly **2601** may include a battery **2664** for supplying power to the components in the handle assembly **2601** as well as providing operating power and/or charging power to the mobile device **18** through the connector **2672** on the docking surface **2668**.

The optic system **2670** secured to the case **2604** may include a structure described with respect to FIG. **10**C or **10**D for purposes of folding the optical path of at least one of a field of illumination of a light source of the mobile device **18** or a field of view of a camera of the mobile device **18** when the mobile device **18** is accommodated in the case **2604**. The field of illumination of a light source of the mobile device **18** or the field of view of a camera of the mobile device **18** is folded from the back surface of the mobile device **18** towards the target area positioned at the top side of the mobile device **18**.

The optic system **2670** may include, or be configured similarly to, any of the other optic systems, or components, thereof, including those described with respect to FIGS. **10**A, **10**B, **10**C, **10**D, **11**A, **11**B, **12**A, **12**B, **12**C, **12**D, **13**, **14**, and **15**.

The handle assembly **2601** may further include a supplemental illumination system **2684**. The supplemental illumination system **2684** may include one or more LED illuminators for emitting illumination towards the front of the handle assembly **2601** (e.g., towards the top of the mobile device **18** when the mobile device **18** is encased within the case **2604**). The supplemental illumination system **2684** may emit targeting illumination (illumination for generating a targeting pattern) and/or exposure illumination (illumination for capturing a barcode).

The supplemental illumination system **2684** may be positioned at the front edge of, or below, the platform **2603** and around a central point of the mobile device **18** when the mobile device **18** is encased within the case **2604**. The distance from the supplemental illumination system **2684** to the top side of the case **2604** may be different from case to case. As such, as shown in FIG. **29**, the case **2604** may include a light pipe **2686** which extends between an illumination receiving end **2688**b and an illumination emitting end **2688**a. The illumination receiving end **2688**b is positioned within the field of illumination of the supplemental illumination system **2684** (e.g., one or more LEDs) and input illumination generated by the supplemental illumination system **2684** into the light pipe **2686**. The illumination emitting end **2688**a is positioned adjacent to the optic system **2670** and emits illumination into the system field of view to illuminate a barcode therein. Light received at the illumination receiving end **2688**b generally propagates through the light pipe **2686** to the illumination emitting end **2688**a based on the principle of total internal reflection. The illumination emitting end **2688***a* may include an optic system **2690** of: i) the curvature of the illumination emitting end **2688***a*, ii) one or more lenses, and/or iii) one or more apertures to modify the intensity distribution of the emitted illumination which is projected into the target area as one of exposure illumination and/or targeting illumination.

If emitted as exposure illumination, the optic system **2690** may function to reduce variation of the intensity of the illumination over the field of view (e.g., even illumination across the field of view). If emitted as targeting illumination the optic system **2690** may function to increase variation of the intensity of the illumination within portions of the field of view to form a visible target pattern. In another embodiment, if emitted as a combination of both targeting illumination and exposure illumination, the optic system **2690** may function to decrease variation in the intensity of the illumination across the field of view (e.g., even illumination across the field of view) with a very sharp and noticeable decrease in the intensity of illumination at approximately the edges of the field of view such that the illumination pattern appears to be a particular shape (e.g., square or rectangular) with even intensity within the field of view and noticeably less illumination, if any, being emitted outside the field of view.

The one or more LEDs of the supplemental illumination system **2684** may comprise one or more LEDs of the same color (such as white LEDs, red LEDs, or blue LEDs) or may comprise LEDs of multiple colors such as white LEDs combined with amber LEDs. The LEDs may be the same color as, or different than, the one or more LEDs of the one or more illumination systems of the mobile device **18**.

In one embodiment, the operating system or other software executing on the mobile device **18** may hinder the use of the light source (e.g., an LED) of the mobile device **18** as targeting illumination if it does not support a sequence of turning the light source on for targeting, off for image capture, and on for targeting at a rate rapid enough for a good user experience. In one embodiment, i) the light source (i.e., a torch) of the mobile device **18** may be used for exposure illumination and the optic system **2670** may function to reduce variation of the intensity of illumination emitted by the light source of the mobile device **18**; and ii) the supplemental illumination system **2684** may be used for targeting illumination.

Alternatively, the light source of the mobile device **18** may be used for targeting and exposure illumination and the optic system **2670** may function to reduce variation of the intensity of illumination emitted by the light source of the mobile device **18** across the field of view with a distinct drop in intensity at approximately the edges of the field of view to yield a particular illumination pattern (e.g., square or rectangular) suitable for targeting a barcode and exposing the barcode during image capture.

Alternatively, the light source of the mobile device **18** may be used for exposure illumination and targeting illumination (e.g., a square or rectangular pattern) and the supplemental illumination system **2684** may be used as additional diffuse bright field illumination or really bright far field illumination. Alternatively, the light source of the mobile device **18** may be used for targeting (e.g., bright field illumination in a square or rectangular pattern) but may be turned off if there is too much glare for exposure. The supplemental illumination system **2684** may be used as diffuse bright field illumination and/or dark field illumination.

FIG. **30** shows another exemplary barcode-reading enhancement accessory **3000** configured as an encapsulating attachment in accordance with another embodiment. FIG. **31** depicts a case and a platform of the exemplary barcode-reading enhancement accessory along with a mobile device. FIG. **32** shows an exemplary barcode-reading enhancement accessory with a different latching mechanism. FIG. **33** shows an exemplary case coupled to a platform, which is configured as an encapsulating attachment.

The barcode-reading enhancement accessory **3000** may comprise a handle assembly **3001***a*, **3001***b* and a case **3004***a*, **3004***b*, **3004***c*. Each case **3004***a*, **3004***b*, **3004***c* is configured for encasing a mobile device (not shown) of a different model or size. The interior and/or exterior dimensions of each case **3004***a*, **3004***b*, **3004***c* may be designed differently for accommodating a particular model or size of a mobile device. The handle assembly **3001***a*, **3001***b* may be generic to all or some of the cases **3004***a*, **3004***b*, **3004***c* so that the same handle assembly may be used with multiple cases **3004***a*, **3004***b*, **3004***c*. Alternatively, each handle assembly **3001***a*, **3001***b* may be designed for a particular mobile device and may be used with a corresponding case designed for the particular mobile device. It should be noted that FIG. **30** depicts three cases **3004***a*, **3004***b*, **3004***c* and two handle assemblies **3001***a*, **3001***b* as an example, and the accessory **3000** may comprise one or more than one cases and one or more than one handle assembly.

The case **3004***a*, **3004***b*, **3004***c* may comprise a cavity **3018***a*, **3018***b*, **3018***c* into which a mobile device **18** is inserted. The cavity **3018***a*, **3018***b*, **3018***c* may be defined by interior surfaces comprising a back side interior surface **3020***a*, **3020***b*, **3020***c*, a face interior surface **3022***a*, **3022***b*, **3022***c*, which is generally parallel to the back side interior surface **3020***a*, **3020***b*, **3020***c*, a top edge interior surface **3040***a*, **3040***b*, **3040***c*, a left edge interior surface **3026***a*, **3026***b*, **3026***c*, and a right edge interior surface **3024***a*, **3024***b*, **3024***c*, which is opposite, and parallel, to the left edge interior surface **3026***a*, **3026***b*, **3026***c*.

The case may have a bottom wall **3005***a*, **3005***b*, **3005***c* as a separate piece. The bottom wall **3005***a*, **3005***b*, **3005***c* is secured to the remaining piece of the case **3004***a*, **3004***b*, **3004***c* with a connecting mechanism to complete the case **3004***a*, **3004***b*, **3004***c*. The case **3004***a*, **3004***b*, **3004***c* is combined with the handle assembly **3001***a*, **3001***b*, more particularly, with the platform **3003***a*, **3003***b* of the handle assembly **3001***a*, **3001***b*. After the case **3004***a*, **3004***b*, **3004***c* is coupled to the handle assembly **3001***a*, **3001***b*, the docking surface **3068***a*, **3068***b* of the handle assembly **3001***a*, **3001***b* may close the cavity **3018***a*, **3018***b*, **3018***c*.

The case **3004***a*, **3004***b*, **3004***c* and the platform **3003***a*, **3003***b* may be combined by sliding the case **3004***a*, **3004***b*, **3004***c* towards the docking surface **3068***a*, **3068***b* of the platform **3003***a*, **3003***b*. The bottom wall **3005***a*, **3005***b*, **3005***c* of the case **3004***a*, **3004***b*, **3004***c* is then closed and locked after the case **3004***a*, **3004***b*, **3004***c* and the platform **3003***a*, **3003***b* are combined. FIG. **33** shows the complete case combined with the platform.

As shown in FIG. **30**, one end of the bottom wall **3005***a*, **3005***b*, **3005***c* and one corner of the case **3004***a*, **3004***b*, **3004***c* may be coupled with a pin so that the bottom wall **3005***a*, **3005***b*, **3005***c* may freely rotate and a latching (fastening or clamping) mechanism may be provided at the other corner of the case **3004***a*, **3004***b*, **3004***c* so that the other end of the bottom wall **3005***a*, **3005***b*, **3005***c* may be secured by the latching mechanism. Alternatively, as shown in FIG. **32**, the bottom wall **3005***a*, **3005***b*, **3005***c* may be coupled to the case **3004***a*, **3004***b*, **3004***c* with screws or pins

3009. Any other conventional means may be used to secure the bottom wall **3005***a*, **3005***b*, **3005***c* to the case **3004***a*, **3004***b*, **3004***c*.

Each of the top edge interior surface **3040***a*, **3040***b*, **3040***c*, the docking surface **3068***a*, **3068***b* of the handle assembly **3001***a*, **3001***b*, the left edge interior surface **3026***a*, **3026***b*, **3026***c*, and the right edge interior surface **3024***a*, **3024***b*, **3024***c* may be generally planar and extend between the back side interior surface **3020***a*, **3020***b*, **3020***c* and the face interior surface **3022***a*, **3022***b*, **3022***c*, and define a perimeter (perimeter edges) of each of the back side interior surface **3020***a*, **3020***b*, **3020***c* and the face interior surface **3022***a*, **3022***b*, **3022***c*. The top edge interior surface **3040***a*, **3040***b*, **3040***c* and the docking surface **3068***a*, **3068***b* of the handle assembly **3001***a*, **3001***b* may each be orthogonal to each of the left edge interior surface **3026***a*, **3026***b*, **3026***c* and the right edge interior surface **3024***a*, **3024***b*, **3024***c*.

The back side interior surface **3020***a*, **3020***b*, **3020***c* may include an aperture **3062***a*, **3062***b*, **3062***c*. The aperture **3062***a*, **3062***b*, **3062***c* may be formed in the center portion of the back side interior surface **3020***a*, **3020***b*, **3020***c* leaving a band in the top, left, and right sides of the back side interior surface **3020***a*, **3020***b*, **3020***c*.

In one embodiment, the handle assembly **3001***a* may include a handle **3002***a* and a platform **3003***a*. In another embodiment, the handle assembly **3001***b* may include a platform **3003***b* and may not have a handle. The handle assembly **3001***a* may be attachable and detachable to the platform **3003***a*.

The platform **3003***a*, **3003***b* includes a platform surface **3066***a*, **3066***b* and a docking surface **3068***a*, **3068***b*. The platform **3003***a*, **3003***b* may have two decks. When the case **3004***a*, **3004***b*, **3004***c* is coupled to the handle assembly **3001***a*, **3001***b*, the case **3004***a*, **3004***b*, **3004***c* is placed on top of the lower deck **3007***a*, **3007***b* and the top surface (the platform surface **3066***a*, **3066***b*) of the upper deck **3008***a*, **3008***b* may: i) be flush (or alternatively may not be flush) with the back side interior surface **3020***a*, **3020***b*, and **3020***c*, and ii) fill (or substantially fill) the aperture **3062***a*, **3062***b*, **3062***c*. After the case **3004***a*, **3004***b*, **3004***c* is coupled to the platform **3003***a*, **3003***b*, the docking surface **3068***a*, **3068***b* becomes a partial bottom edge interior surface of the case **3004***a*, **3004***b*, **3004***c*.

As shown in FIG. **31**, the case **3004***a*, **3004***b*, **3004***c* (with the mobile device **18** encased in it) is coupled to the handle assembly **3001***a*, **3001***b* before using as a barcode reading device. For coupling the case **3004***a*, **3004***b*, **3004***c* to the handle assembly **3001***a*, **3001***b*, a coupling structure may be provided in the case **3004***a*, **3004***b*, **3004***c* and the handle assembly **3001***a*, **3001***b*. For example, a tongue (or a groove) may be formed along the left and right edges of the platform surface **3066***a*, **3066***b* and a groove (or a tongue) may be formed along the left and right edges of the aperture **3062***a*, **3062***b*, **3062***c* of the back side interior surface of the case **3004***a*, **3004***b*, **3004***c* so that the case **3004***a*, **3004***b*, **3004***c* may be coupled to the handle assembly **3001***a*, **3001***b* by sliding the tongue along the groove. Alternatively, the left and right edges of the platform surface **3066***a*, **3066***b* and the aperture **3062***a*, **3062***b*, **3062***c* may have the matching cross-section (e.g., a slanted edge) so that the platform **3003***a*, **3003***b* and the case **3004***a*, **3004***b*, **3004***c* may be secured by simply sliding the case **3004***a*, **3004***b*, **3004***c* towards the docking surface **3068***a*, **3068***b* along the matched edges of the platform surface **3066***a*, **3066***b* and the aperture **3062***a*, **3062***b*, **3062***c*. Alternatively or additionally, a ridge and a rail may be formed along the left and right edges of the platform surface **3066***a*, **3066***b*, and the left and right edges of the aperture **3062***a*, **3062***b*, **3062***c*. The ridge/rail combination may provide additional strength for securing the case **3004***a*, **3004***b*, **3004***c* to the handle assembly **3001***a*, **3001***b* and provide greater strength against torsional forces (in the direction **2692** as shown in FIG. **29**) than if the case **3004***a*, **3004***b*, **3004***c* is simply mounted to the handle assembly **3001***a*, **3001***b*.

The face interior surface **3022***a*, **3022***b*, **3022***c* may also include an aperture through which a display screen **43** of a mobile device **18** may be viewed and as such the face interior surface **3022***a*, **3022***b*, **3022***c* may be a thin band which extends around the periphery defined by the top edge interior surface **3040***a*, **3040***b*, **3040***c*, the docking surface **3068***a*, **3068***b*, the left edge interior surface **3026***a*, **3026***b*, **3026***c*, and the right edge interior surface **3024***a*, **3024***b*, **3024***c*.

At least a portion of the interior surfaces (shown in FIG. **30**) of the case **3004***a*, **3004***b*, **3004***c* (including the docking surface **3068***a*, **3068***b* of the handle assembly **3001***a*, **3001***b*) conform to at least a portion of an exterior surface of the mobile device **18** for which the case **3004***a*, **3004***b*, **3004***c* is configured. Each case **3004***a*, **3004***b*, **3004***c* may have different dimensions of its interior surfaces to fit a mobile device **18** of a different model or size. More specifically, each case **3004***a*, **3004***b*, **3004***c* may comprise interior surfaces into which a particular model or size of a mobile device **18** will securely fit. For example, case **3004***a* may be configured to fit the Apple iPhone 6 Plus®, case **3004***b* may be configured to fit the Apple iPhone 6®, and case **3004***c* may be configured to fit the Apple iPhone 5/5s®.

When the case **3004***a*, **3004***b*, **3004***c* carrying a mobile device **18** is coupled to the handle assembly **3001***a*, **3001***b*, the position of the mobile device **18** with respect to the accessory is referred to as the "operating position."

An optic system **3070** (as shown in FIG. **33**) may be secured to the case **3004***a*, **3004***b*, **3004***c*. The optic system **3070** is configured to fold an optical path of at least one of a field of illumination of a light source of the mobile device **18** or a field of view of a camera of the mobile device **18** when the mobile device **18** is accommodated in the case **3004***a*, **3004***b*, **3004***c*.

When the mobile device **18** is in the operating position, the optic system **3070** may be within at least one of the field of illumination of the white light source of the mobile device **18** and/or the field of view of the camera of the mobile device **18**. The dimensions of the case **3004***a*, **3004***b*, **3004***c* are selected so that the mobile device **18** is positioned within the cavity **3018***a*, **3018***b*, **3018***c* of the case **3004***a*, **3004***b*, **3004***c* so that the optic system **3070** is within at least one of the field of illumination of the white light source of the mobile device **18** and/or the field of view of the camera of the mobile device **18**.

The optic system **2070** may include, or be configured similarly to, any of the other optic systems, or components, thereof, including those described with respect to FIGS. **10**A, **10**B, **10**C, **10**D, **11**A, **11**B, **12**A, **12**B, **12**C, **12**D, **13**, **14**, and **15**.

A connector **3072** (e.g., the Apple Lightning Connector®), as shown in FIG. **33**, may be provided on the docking surface **3068***a*, **3068***b* of the handle assembly **3001***a*, **3001***b* for connection to the mating connector **3032** (shown in FIG. **31**) of the mobile device **18** when the combined mobile device and case is coupled to the handle assembly **3001***a*, **3001***b*. When the mobile device **18** is in the operating position, the connector **3072** on the handle assembly is aligned both vertically and horizontally with the mating connector **3032** on the mobile device **18**. The dimensions and shape of the case **3004***a*, **3004***b*, **3004***c* are selected so that when the combination of the case and the mobile device is coupled to the handle assembly **3001***a*, **3001***b*, the connector **3072** on the handle assembly is aligned both vertically and horizontally with the mating connector **3032** on the mobile device **18**.

Typically the mating connector **3032** on the mobile device **18** will be in the center (between the left and right sides when the mobile device **18** is viewed in a portrait mode) of the mobile device **18** on its bottom surface. There are certain scenarios where all of the mobile devices **18** for which the cases **3004***a*, **3004***b*, **3004***c* are designed may have the mating connector **3032** positioned at the same distance from the back side exterior surface of the mobile device **18**. In these scenarios, that distance can be used for the distance between the platform surface **3066***a*, **3066***b* and the connector **3072** of the handle assembly **3001***a*, **3001***b*, and the back side interior surface **3020***a*, **3020***b*, **3020***c* of each case **3004***a*, **3004***b*, **3004***c* may be flush with the platform surface **3066***a*, **3066***b*.

However, there may be other cases where the distance between the mating connector **3032** on a mobile device **18** and the mobile device's back side exterior surface varies among the mobile devices for which cases are designed. In these cases, the back side interior surface **3020***a*, **3020***b*, **3020***c* of each case **3004***a*, **3004***b*, **3004***c* may not be flush with the platform surface **3066***a*, **3066***b* and the mobile device **18** should be raised above the platform surface **3066***a*, **3066***b* to align the mating connector **3032** of the mobile device **18** to the connector **3072** on the docking surface **3068***a*, **3068***b*. For example, a tongue **3065** may be provided in the back side interior surface **3020***c* of the case and a matching slot **3063** may be formed in the upper deck **3008***a*, **3008***b* of the platform **3003***a*, **3003***b*. The thickness of the tongue **3065** can vary to raise the mobile device **18** above the platform surface **3066***a*, **3066***b* to ensure alignment of the connector **3072** on the docking surface **3068***a*, **3068***b* with the mating connector **3032** on the mobile device **18**.

Each case **3004***a*, **3004***b*, **3004***c* may include one or more apertures **3074***a*, **3074***b*, **3074***c*, **3074***d* within one or more of its walls to expose control buttons or switches on the mobile device **18** when the mobile device **18** is inserted into the case **3004***a*, **3004***b*, **3004***c*. Each case **3004***a*, **3004***b*, **3004***c* is designed for a mobile device **18** of a particular model or size so that each aperture **3074***a*, **3074***b*, **3074***c*, **3074***d* is positioned for the control buttons or switches on the corresponding mobile device **18**. Alternatively, instead of the aperture(s), a flexible button or switch may be formed in the corresponding position in the wall(s) of the case **3004***a*, **3004***b*, **3004***c* so that the control buttons or switches on the mobile device **18** may be operated through the flexible button or switch formed in the wall(s) of the case **3004***a*, **3004***b*, **3004***c*.

The handle **3002***a* extends downward away from the platform **3003***a*. The handle **3002***a* is sized and shaped to be gripped by an operator. When held by the operator, the display screen **43** of the mobile device **18** is visible to an operator looking downward. A trigger switch (not shown in FIG. **30** but similar to the trigger switch **2680** shown in FIG. **29**) may be provided on the handle **3002***a* to enable the operator to trigger reading of a barcode. In case where the handle assembly **3001***b* does not include a handle, a trigger switch **3080** may be provided, for example, on the side of the case, as shown in FIG. **33**. The trigger switch activates a trigger or barcode rendering circuit in the handle assembly **3001***a*, **3001***b*. The handle assembly **3001***a*, **3001***b* may include a battery for supplying power to the components in the handle assembly **3001***a*, **3001***b* as well as providing operating power and/or charging power to the mobile device **18** through the connector **3072**.

Referring to FIG. **33**, the optic system **3070** secured to the case **3004** may include a structure described with respect to FIG. **10**C or **10**D for purposes of folding the optical path of at least one of a field of illumination of a light source of the mobile device **18** or a field of view of a camera of the mobile device **18** when the mobile device **18** is accommodated in the case **3004**. The field of illumination of a light source of the mobile device **18** or the field of view of a camera of the mobile device **18** is folded from the back surface of the mobile device **18** towards the target area positioned at the top side of the mobile device **18**.

Referring to FIG. **30**, the handle assembly **3001***a*, **3001***b* may further include a supplemental illumination system that is similar to the supplemental illumination system **2684** in FIG. **29**. The optic system including the light pipe **2686**, the illumination emitting and receiving ends **2688***a*, **2688***b*, and the optic system **2690** may also be provided to the case. Details of the supplemental illumination system and the optic systems will not be provided here for simplicity. The supplemental illumination system may include one or more LED illuminators for emitting illumination towards the front of the handle assembly **3001***a*, **3001***b* (e.g., towards the top of the mobile device **18** when the mobile device **18** is encased within the case **3004***a*, **3004***b*, **3004***c*). The supplemental illumination system may be targeting illumination (illumination for generating a targeting pattern) and/or exposure illumination (illumination for capturing a barcode).

The barcode-reading enhancement system of the present invention may include a barcode-reading application **500** that may be obtained from the application server **22***a*, **22***b* (shown in FIG. **1**) and installed on the mobile device **18** as described with respect to FIG. **3**A.

FIG. **16** shows a block diagram of an exemplary barcode application **500**. The exemplary barcode application **500** may include permutations of a user interface control method **502**, image capture control methods **504**, a decoder **506**, and a data control method **508**.

FIG. **17** depicts a state machine **642** useful for user interface control methods **502** of the barcode application **500**. The state machine **642** may operate either in a user interface state **644** or in a data collection state **646**.

When in the user interface state **644**, the (capacitive touch) display screen **66** and the backlight for the display screen are active and the contents of the display screen **66** may be controlled by the barcode application **500**. When in the data collection state **646**, the (capacitive touch) display screen **66** may be turned off; the (capacitive touch) display screen **66** may be turned on, but the backlight may be turned off; or both the (capacitive touch) display screen **66** and the backlight may be turned on, but the backlight intensity may be set to a minimum. The data collection state **646** is intended for conserving power (i.e., for extending battery life) when the operator is using the mobile device **18** to read barcodes and does not need to simultaneously use the (captive touch) display screen **66** for manual data entry.

To transition **648** from the user interface state **644** to the data collection state **646**, the barcode application **500** utilizing the data control methods **508** may make a processing call to the operating system of the mobile device **18** requesting to i) turn off the display and backlight; ii) turn off the backlight (in the event the operating system does not make the function of turning off the display available to the application); or iii) turn the backlight power to a minimum (in the event the operating system does not make the function of turning off the display or turning off the backlight available to the application). If none of the foregoing options are available, the barcode application may simply write a black image to the display and enter a state where all input though the touch panel is ignored, thereby giving the appearance that the display has been turned off.

When in the data collection state **646**, multiple barcodes can be read in sequence (utilizing the camera and targeting structure described herein but not requiring use of the display for targeting) and processed, stored, and/or transmitted by the application without requiring any user interaction with the user interface. Examples of the functions that may be performed by the application when in the data collection state without requiring user input include the functions of the relay application described in co-pending U.S. patent application Ser. No. 14/319,193.

When a transition **650** to the user interface state **644** is required, the barcode application **500** may make a processing call to the operating system of the mobile device **18** requesting to i) turn on the display (i.e., the touch panel or backlight) in the event that these are turned off during the data collection state **646**; ii) turn on the backlight (in the event the operating system does not make the function of turning off the display available to the application and therefore the display remains "on" while the backlight remains "off" during the data collection state **646**); or iii) turn the backlight power up to a present level (in the event the operating system does not make the function of turning off the display or turning off the backlight available to the application, both remain "on" during the data collection state **646** while the backlight power has been turned down).

Events that may trigger transition **648** from the user interface state **644** to the data collection state **646** include user activation of a hardware control on the mobile device **18** or activation of a software control present on the display screen when in the user interface state **644**. Events that may trigger transition **650** from the data collection state **646** to the user interface state **644** include user activation of a hardware control on the mobile device **18** or a signal from a remote software application which may include the application to which the mobile device **18** is sending decoded barcode data.

Returning to FIG. **16**, the image capture control methods **504** may comprise permutations of color format control methods **504***a*, autofocus control methods **504***b*, auto-white balance control methods **504***c*, resolution and pre-processing control methods **504***d*, gain and shutter control methods **504***e*, and target and exposure illumination and shutter control methods **504***f*.

Permutations of these methods may be performed when the barcode application **500** enters the data collection state **646** such that the mobile device **18** is configured for barcode reading prior to the operator triggering or otherwise initiating a barcode read. Permutation of these methods may be performed immediately following an unsuccessful decode with adjustments made to certain image capture settings based on analysis of the image that yielded the unsuccessful decode so that the mobile device **18** is re-configured for barcode reading prior to the next image capture. Permutations of these methods may be performed after the user has triggered or otherwise initiated a barcode read but prior to actual image capture to configure the mobile device **18** for the image capture.

As stated with respect to FIGS. **2**A and **2**E, the camera assembly **36** may be capable of generating both Y.U.V and R.G.B. color formatted outputs. The color format control methods **504***a* may query whether the image sensor and/or associated circuitry has been set to provide an output in the Y.U.V. color space. If not, the color format control method **504***a* may issue a command to the operating system **48**, the processor **44**, or the system-on-chip circuits **92** to set the image sensor output to the Y.U.V. color space.

The R.G.B. format may commonly be used for general-purpose photography. However, for barcode reading and/or decoding, it may be advantageous to use the Y.U.V. format instead. This is because decoding a barcode image may be mostly reliant upon the pattern defined by the luminous intensity **168** (shown in FIG. **2**E) of each pixel in the barcode image. Optionally, the first chromatic **170** and the second chromatic **172** may even be ignored by the application that decodes the barcode image.

Thus, the output module **91** of the system-on-chip circuits **92** may be set to provide the digital image output **162** in the form of the Y.U.V. data format **166** (or use Y.U.V data for the input to image processing circuits within the system-on-chip circuits **92**). Accordingly, the application **50** may instruct the output module **91**, directly, through the operating system **48**, or through other control circuitry, to cause the output module **91** to provide the digital image output **162**, to use, for image processing circuits, data in the Y.U.V format when the photo sensor **42** is to be used for capturing a barcode image and to return in the R.G.B. format for general photography when barcode capturing operations are complete.

In one embodiment, for barcode images, the output module **91** may be set to provide the digital image output **162**, or use for image processing data in the form of the luminous intensity **168** for each pixel, and the first chromatic **170** and the second chromatic **172** may not even be provided or used. This may reduce the traffic on the data bus, reduce image processing time for image processing circuits, reduce the processing load of the processor **44**, and/or save space in the image data buffer **89** of the memory **46**.

As discussed with respect to FIG. **2**A, the mobile device **18** may include an autofocus module **98**. The autofocus module **98** may be optimized for photography. The image capture control methods **504** of the barcode application **500** may include autofocus control methods **504***b* for adjusting the autofocus settings of the autofocus module **98** for barcode image capture. More specifically, the distance between the mobile device **18** and a barcode **142** within a target area **140** may be within a relatively predictable range of distances which is a much smaller range of distances between the mobile device and the subject of a general-purpose photograph. Thus, using customized autofocus settings for barcode image capture may facilitate obtaining proper focus and/or expedite the image capture process.

FIG. **18**A illustrates exemplary autofocus options in the form of a graph **610**. As shown, a horizontal axis **612** represents a nonlinear continuum of focus positions (e.g., object distance that is best focused onto the photo sensor). The camera assembly **36** of the mobile device **18** may have a full range **614** of focus positions. However, those on the upper and lower ends of the full range **614** may not be needed for barcode image capture because they represent object distances which are less than, or greater than, the typical distance between a barcode reader and a barcode. Accordingly, the autofocus settings of the camera assembly **36** may be configured specifically for barcode image capture, for example, via commands to the autofocus module **98** (or the operating system **48** controlling the autofocus module **98**).

By way of example, the commands to the autofocus module **98** (or the operating system **48**) may allow the camera assembly **36** to focus at object distances within a limited range **616**. The limited range **616** may represent the useful range of object distances for barcode image capture, and exclude object distances too close to the mobile device **18** and object distances too far from the mobile device **18** for barcode reading.

As another example, the commands to the autofocus module **98** (or the operating system **48**) may limit focus positions to discrete positions such as a first position **618***a*, a second position **618***b*, and a third position **618***c*. The first position **618***a*, the second position **618***b*, and the third position **618***c* may represent useful object distances for barcode image capture. The optic system may have sufficient depth of field at each of the discrete positions to accommodate image capture of a barcode within the target area **140** with sufficient sharpness for decoding.

Setting autofocus to one of a plurality of discrete focus settings may utilize a feedback-loop algorithm that is faster than the feedback-loop algorithms for autofocus when performing photography wherein the image is analyzed for sharpness and the best focus position is determined within the entire range.

As discussed with respect to FIG. **2**A, the system-on-chip circuits **92** may include an auto-white balance module **93**. As such the auto-white balance control methods **504***c* of the barcode application **500** (shown in FIG. **16**) may issue a command to the operating system **48**, the processor **44**, or the auto-white balance module **93** to disable the auto-white balance function of the image sensor and/or associated circuitry. This may be done, as indicated previously, to avoid degrading contrast when a narrow band of illumination frequency is focused onto the image sensor for barcode reading.

As such, for barcode images, the output module **91** may be set to provide the digital image output **162**, or use for image processing data that has not been subjected to modification by the disabled auto-white balance module **93**.

The resolution and pre-processing control methods **504***d* may control the resolution for the output image as well as other image processing which may be performed on the output image prior to storing in the image data buffer **89** for decoding. Speed enhancements for image processing and decoding may be obtained by altering the resolution of the captured image. While high resolution images (e.g. 8 megapixels or more) may be desirable for conventional photography, this resolution may not be needed for barcode imaging and decoding. As long as the resolution is sufficient for successful decoding of a barcode, there is typically no need for an image of greater resolution.

Selection of the resolution may be done, for example, based on the type of barcode to be scanned, the size of the barcode within the output image, and other factors, which may be determined from previous images captured of the barcode. The resolution selected may be full resolution (i.e., one output pixel for each pixel captured by the image sensor) or binned (i.e., one output pixel for each group of x pixels captured by the image sensor).

FIG. **18**B illustrates exemplary resolution binning methods that can be used to reduce the resolution of a barcode image. An exemplary image may be captured, by way of example, in three different ways. In a first scheme **620**, no binning may be applied, and the image output may be the native resolution (full resolution) of the photo sensor **42** (i.e., one digital pixel value for each pixel captured by the photo sensor **42**). In a second scheme **622**, moderate binning may be applied so that the output has one digital pixel value, for example, for every four pixels captured by the photo sensor **42**. The resulting output image data may thus be one-quarter of the resolution of the captured image data. In a third scheme **624**, more aggressive binning may be applied so that the output has one digital pixel value, for example, for every six pixels captured by the photo sensor **42**. The resulting output image data may thus be vertical binning (non-square) and one-sixth of the resolution of the captured image data.

When binning is applied, various mathematical algorithms may be used to obtain the value of an output pixel, based on its constituent pixels of the captured image. According to some examples, the intensity values of the constituent pixels may be averaged to provide the value of the resulting output pixel.

The foregoing description is illustrative of certain types of image processing that may be performed on image data while the image data is being transferred through the hardware circuits **90** and DMA **86** to the image data buffer **89**. A more complete description of image processing algorithms that may be implemented in the hardware circuits **90** (or the system-on-chip circuits **92**) is included in U.S. patent application Ser. No. 14/717,112. In the exemplary embodiment, the image resolution and pre-processing control methods **504***d* of the barcode application **500** may provide instructions to the hardware circuits **90**, the system-on-chip circuits **92**, and/or the operating system to set any of the foregoing image pre-processing options as well as image pre-processing options described in U.S. patent application Ser. No. 14/171,112.

In all cases, setting the resolution and image pre-processing selections may entail the resolution and pre-processing control methods **504***d* issuing a command to the operating system **48**, the processor **44**, the applicable image processing circuits within the hardware circuits **90**, or the applicable image processing circuits within the system-on-chip circuits **92**.

Gain and shutter control methods **504***e* may comprise setting image capture parameter values for one or more image frames to be sequentially captured, including a gain setting and an exposure setting for each frame as described in more detail in U.S. patent application Ser. No. 14/171,112.

FIG. **19**A depicts an exemplary embodiment of target and exposure illumination and shutter control methods **504***f* in accordance with one embodiment. Step **542** represents receiving a trigger signal indicating that a barcode is to be read. The trigger signal may be received in several alternative ways as represented by steps **542***a*-**542***e*. As discussed, the barcode application **500** may have a user interface (not shown) with one or more graphical elements displayed on the display screen **66**. The user may use such graphical elements to initiate the barcode scanning process (for example, by tapping a "scan" soft button on the display screen **66**) (**542***a*).

Alternatively, the application may monitor the microphone connector **34***b* and the trigger signal may be a microphone input signal generated by the attachment as described with respect to FIG. **14** (**542***b*).

Alternatively, the application may monitor the data connector **64***b* and the trigger signal may be a data input signal generated by the attachment as described with respect to FIG. **13** (**542***c*).

Alternatively, the application may monitor the wireless communication system **52** and the trigger signal may be a wireless radio frequency (RF) trigger signal generated by the attachment (**542***d*).

Alternatively, the application may monitor the target area **140** utilizing a sensor and the trigger signal may be automatically generated by the application detecting the presence of a barcode within the target area **140** (**542***e*).

Step **544** represents pulsing the target illumination to generate a distinct illumination pattern within the target area **140** to assist the operator in aiming the mobile device **18** with respect to the barcode for image capture. The pulse may be generated for a duration sufficient for the operator to aim the mobile device **18** or may be generated for a shorter period of time (on the order of 10 ms). As discussed, the target illumination may be generated by the white light source **84** of the mobile device **18** (step **544***a*) or may be an external target illumination source (step **544***b*) within the attachment.

Step **546** represents a step of activating the exposure illumination. In certain embodiments ambient illumination is used for providing diffuse illumination for image capture of a barcode. In these embodiments step **546** may not be performed. In other embodiments the exposure illumination may be activated for image capture (step **546**). As discussed, the exposure illumination may be generated by the white light source **84** of the mobile device **18** (e.g., a mobile device torch) (step **546***a*) or may be an external exposure illumination source (step **546***b*) within the attachment. The barcode image is then captured (step **548**).

Step **550** represents determining whether there has been a successful decode of the barcode represented in the captured image. If it has been successful, then the method may end. If there has not been a successful decode, the image capture parameters may be adjusted at step **552** and the target illumination system may again be pulsed to further assist the user in aiming the mobile device **18** with respect to the barcode at step **544**. It is recognized that several repeats of this process may be required for: i) the operator to properly aim the mobile device **18** with respect to the barcode (if the target illumination pulse is short), and ii) the operator to have a correct combination of image capture parameters such that the resulting image is decodable.

FIG. **19**B depicts another exemplary embodiment of target and exposure illumination and shutter control methods **504***f* in accordance with another embodiment. Some of the steps in FIGS. **19**A and **19**B are the same and such steps will not be explained in detail for simplicity.

Step **542'** (i.e., any one of **542***a*' to **542***e*') represents receiving a trigger signal indicating that a barcode is to be read.

Step **554'** represents turning on a combination of targeting and exposure illumination. As discussed with respect to FIG. **8**D, the intense targeting pattern **400** may include diffuse illumination across a region that coincides with the system field of view **207** such that the targeting illumination is also the exposure illumination. As discussed, the targeting and exposure illumination may be generated by the white light source **84** of the mobile device **18** (step **554***a*') or may be an external illumination source within the attachment (step **554***b*').

Step **548'** represents image capture of a barcode, step **550'** represents determining whether there was a successful decode, and step **552'** represents adjusting image capture parameters based on the previous image captured, all as discussed with respect to FIG. **19**A. If there is a successful decoding the targeting exposure illumination may be turned off at step **556'**. If the decoding is not successful another image of the barcode may be captured (step **548'**) following adjustment of image capture parameters (step **552'**) if any.

FIG. **19**C represents a filtering arrangement for the targeting illumination and the supplemental optics which enable use of the methods of FIG. **19**B even if the intense targeting illumination pattern is not also a diffuse illumination pattern across the entire barcode within the field of view.

The visible spectrum **560** generally ranges from about 430 nm to approximately 660 nm. In a first embodiment the targeting illumination structure may include a first narrow band pass filter which passes a narrow band of illumination (e.g., the band **564**) within the visible spectrum **560** while attenuating illumination (e.g., the band **566***a*) below the band **564** and illumination (e.g., the band **566***b*) above the band **564**. In an exemplary embodiment, the first narrow band pass filter may have its narrow pass band centered at a wavelength between 430 nm and 470 nm which are the wavelengths corresponding to blue illumination. When such a filter is used to filter white illumination, the color of the intense targeting illumination passed by the band pass filter would appear blue.

In another embodiment, the targeting illumination structure may include a low pass filter. The low pass filter passes wavelengths of illumination (e.g., the band **570**) which are within the visible spectrum **560** below a predetermined threshold while attenuating wavelengths of illumination (e.g., the band **572**) above the threshold. In an exemplary embodiment, the predetermined threshold may be between 470 nm and 500 nm such that the pass band (i.e., the passed illumination spectrum) is substantially blue. When such a filter is used to filter white illumination, the color of the illumination passed by the filter appears blue.

Although the first narrow band pass filter is depicted as having very distinct edges (e.g. wavelengths within the pass band **564** are passed with no attenuation and wavelengths outside the pass band **564** are completely attenuated) it is recognized in the art that the edges are not as distinct as depicted, and some illumination within the pass band **564** will also be attenuated and some illumination outside of the pass band (i.e., the bands **566***a* and **566***b*) will also be passed. A most efficient filter will minimize the amount of illumination within the pass band **564** that is attenuated and further minimize the amount of illumination that is outside of the pass band (i.e., the bands **566***a* and **566***b*) to be passed.

Similarly, although the low pass filter is depicted as having a very distinct edge at the threshold (e.g., wavelengths below the threshold are passed with no attenuation and wavelengths above the threshold are completely attenuated) it is recognized in the art that the edge is not as distinct as depicted, and some illumination within the band **570** will be attenuated and some illumination within the band **572** will be passed. A most efficient filter will minimize the amount of illumination within the band **570** that is attenuated and further minimize the amount of illumination in the band **572** that is outside of the band **570** to be passed.

In other embodiments, the targeting illumination structure may include a high pass filter. The high pass filter passes wavelengths of illumination (e.g., the band **578**) which are within the visible spectrum **560** above a predetermined threshold while attenuating wavelengths of illumination (e.g., the band **576**) below the threshold. In an exemplary embodiment, the predetermined threshold may be 500 nm such that the pass band **578** includes the entire visible spectrum excluding illumination which is substantially blue.

As with the low pass filter, the high pass filter is depicted as having a very distinct edge at the threshold (e.g. wavelengths above the threshold are passed with no attenuation and wavelengths below the threshold are completely attenuated) it is recognized in the art that the edge is not as distinct as depicted, and some illumination above the threshold will be attenuated and some illumination below the threshold will be passed. A most efficient filter will minimize the amount of illumination above the threshold that is attenuated and further minimize the amount of illumination below the threshold that is passed.

It should be appreciated that when illumination from a white light source **84** of a mobile device **18** is filtered utilizing a narrow band pass filter (e.g., a pass band **564**) or a low pass filter (e.g., a pass band **570**) and the illumination incident on the camera lens is filtered by a high pass filter (e.g., passing the band **578**), the illumination generated by the white light source **84**, as filtered, may not be visible to the camera because the portion of the illumination passed by the band pass filter (e.g., passing the band **564**) or the low pass filter (e.g., passing the band **570**) is attenuated by the high pass filter. As such, if the white light source **84** is used for generating an intense targeting illumination pattern within the field of view **207**, the targeting pattern may not be visible to the camera (e.g., attenuated by the high pass filter) and ambient illumination passed by the high pass filter (e.g., passing the band **578**) is visible to the camera and is typically sufficient for imaging and decoding a barcode.

This structure enables the accessory to further utilize optics to generate a targeting pattern utilizing the white light source **84** (filtered before or after being shaped by the optic) and enables the intense targeting illumination pattern to continue to illuminate the barcode during image capture (enabling the operator to aim the mobile device **18** with respect to the barcode) without the targeting pattern being visible to the camera and producing hot regions (intense illumination) corresponding to the targeting pattern within the image.

Returning to FIG. **16**, the decoder **506** of the barcode application **500** may comprise known methods for image processing and decoding, including methods described in U.S. patent application Ser. No. 14/717,112. As discussed with respect to FIGS. **19**A and **19**B, if decoding is unsuccessful, then a new barcode image may need to be captured. This may be done by returning to the image capture control methods **504** and selecting new image capture parameters. This process may be repeated until the barcode image has been successfully decoded, or until the user cancels further image capture and/or decoding attempts.

In general the data control methods **508** of the barcode application **500** control what processes are performed on data decoded from the barcode **142** (decoded data) within the target area **140**. In more detail, and with reference to FIG. **1**, in a first aspect the data control methods **508** may function as a mobile client to a remote non-legacy system which supports maintaining a Transmission Control Protocol/Internet Protocol (TCP/IP) connection with mobile devices (such as mobile device **18**) via the LAN **12** for exchanging data with the mobile device **18** (including receiving decoded data from the mobile device **18**) and controlling operation of certain aspects of the barcode application **500**.

In a second aspect, the data control methods **508** may function as a mobile client to an intermediary device. The intermediary device supports maintaining a TCP/IP connection with mobile devices (such as mobile device **18**) via the LAN **12** for receiving decoded data from the mobile device **18**. In turn the intermediary device may further support providing decoded data received from the mobile device **18** to a legacy system. This is useful when the legacy system is incapable of receiving decoded data directly from the mobile device **18** via a TCP/IP connection and therefore the barcode application **500** may function independently of, and requires no compatibility with, the communication protocols and functions of the legacy system, including those used for communication between the legacy system and the intermediary device. The intermediary device may communicate with the legacy system, which may be a TCP/IP connection separate from the TCP/IP connection through which the mobile device **18** communicates with the intermediary device.

In accordance with an embodiment, a non-transitory computer-readable medium is provided for storing instructions for a barcode-reading application for a mobile device. The mobile device includes a camera assembly, a network interface, a memory, and a processor for executing the barcode-reading application including a decoder. The non-transitory computer-readable medium may include a code for controlling the camera assembly to capture an image of a barcode, decoding the image of the barcode to generate decoded data, and processing the decoded data; a code for controlling the network interface to establish a network connection to a licensing server and obtaining a license code from the licensing server when in a base mode of operation; a code for subjecting the license code to a predetermined algorithm and determining at least one operating permission authorized by the license code; a code for enabling an enhanced mode of operation; and a code for implementing at least one enhanced barcode-reading function which corresponds to the at least one operating permission authorized by the license code when in the enhanced mode of operation.

The at least one enhanced barcode-reading function may include a function of decoding a barcode symbology that the decoder is restricted from decoding in the base mode of operation. Alternatively or additionally, the at least one enhanced barcode-reading function may include a function of decoding multiple barcodes in sequence at a rate that is faster than a rate at which the barcode-reading application can decode multiple barcodes in sequence in the base mode of operation. Alternatively or additionally, the at least one enhanced barcode-reading function may include a function of decoding a quantity of barcodes of a particular symbology that exceeds a restricted quantity of barcodes of the particular symbology that the barcode-reading application can decode in the base mode of operation.

Alternatively or additionally, the at least one enhanced barcode-reading function may remove a demonstration restriction function under which the barcode-reading application functions in the base mode of operation. The demonstration restriction function may be at least one of: i) a function that scrambles decoded data from a barcode of at least one symbology; ii) a function that restricts the decoded data or scrambled decoded data from a barcode of at least one symbology from being made available for further processing; or iii) a function that restricts the decoded data or the scrambled decoded data from a barcode of at least one symbology from being displayed on a display screen of the mobile device.

Alternatively or additionally, the at least one enhanced barcode-reading function may enable at least one enhanced image processing function that improves an ability to decode an image of a barcode and is not operable when the decoder operates in the base mode of operation.

The base mode of operation may include a base decoding mode of operation and a demonstration mode of operation. The computer-readable storage medium may further include, for the base decoding mode of operation, a code for driving the camera assembly to capture an image of a barcode, a code for applying base decoder functions to the image to identify a barcode symbology, a code for decoding the barcode and making decoded data available for further processing if the barcode symbology is a base symbology, and a code for entering the demonstration mode of operation if the barcode symbology is not the base symbology. The computer-readable storage medium may further include, for the demonstration mode of operation, a code for applying at least one enhanced barcode-reading function to decode the barcode, and a code for performing at least one of: i) outputting an indication of successful decoding of the barcode, or ii) implementing a restriction function. The restriction function may be at least one of: i) a function that scrambles decoded data, ii) a function that restricts the decoded data or scrambled decoded data from being made available for further processing by at least one application executing on the mobile device, or iii) a function that restricts the decoded data or the scrambled decoded data from being displayed on a display screen of the mobile device.

The non-transitory computer-readable medium may further include a code for performing an upgrade function in the demonstration mode of operation. The upgrade function may enable a user selection to obtain the license code, obtain the license code based on the user selection, establish a network connection to the licensing server, and obtain the license code from the licensing server.

The non-transitory computer-readable medium may further include a code, in order to obtain the license code from the licensing server, for communicating to the licensing server one of: i) a unique identification code of the mobile device; or ii) a user identification code identifying a controller of the mobile device.

FIG. **37**A depicts a perspective view of a mobile device **18** encapsulated within an encapsulating attachment **3700**. The encapsulating attachment **3700** may encapsulate the mobile device **18** as described with respect to FIGS. **5**A, **5**B, **12**A, **12**B, **12**C, **12**D, **13**, and **14**. Alternatively, the encapsulating attachment **3700** may be a combination of an outer case and an inner carriage (or a handle assembly with an encapsulating case) as described with respect to FIGS. **23**, **24**A, **24**B, **25**, **26**, **27**, **28**, **29**, **30**, **31**, **32**, and **33**. The encapsulating attachment **3700** is used as a barcode reading enhancement accessory (which may be simply referred to as an "accessory") to enhance a barcode reading capability of a mobile device **18**. The barcode reading enhancement accessory and a barcode reading application that may be downloaded from a remote server into the mobile device **18** and executed by a processor of the mobile device **18** may comprise a barcode-reading system. FIGS. **37**A-**37**C and **38** do not show the details of the mobile device **18**, but the mobile device **18** may be similar to the one depicted in FIGS. **2**A-**2**C wherein a camera assembly **36** (including a lens assembly **40**) and a white light source **84** are positioned, for example, near the upper left side of the back surface **74** of the mobile device **18**.

The encapsulating attachment **3700** includes an optics module **3702** which folds both the field of view **38** of the camera assembly **36** of the mobile device **18** and the field of illumination of the white light source **84** of the mobile device **18** similar to the folded field of view and/or folded field of illumination described with respect to FIGS. **10**C, **10**D, **11**A, **11**B, **14**, **25**, **28**, **29** and **33**. A barcode to be read is presented in the target area which is located around the top side of the mobile device **18**.

The optics module **3702** is moveable with respect to the body **3701** of the encapsulating attachment **3700** such that the optics module **3702** may be repositionable between: i) a first position (i.e., an active position) where the optics module **3702** is positioned within the field of view of the camera assembly **36** of the mobile device **18** and the field of illumination of the white light source **84** of the mobile device **18**; and ii) a second position (i.e., an inactive position) where the optics module **3702** is positioned outside of both the field of view of the camera assembly **36** of the mobile device **18** and the field of illumination of the white light source **84** of the mobile device **18**. The field of view of the camera assembly **36** and the field of illumination of the white light source **84** may be unobstructed by the optics module **3702** in the second position.

The encapsulating attachment **3700** may include an aperture (not shown) extending around a periphery of both the field of view of the camera assembly **36** and the field of illumination of the white light source **84**. Through the aperture, the field of view of the camera assembly **36** and the field of illumination of the white light source **84** may extend to be incident on the optics module **3702** when the optics module **3702** is in the first position, and the field of view and the field of illumination may extend beyond the back side of the mobile device **18** when the optics module **3702** is in the second position.

The optics module **3702** may be movable between the first position and the second position by sliding the optics module **3702** within a track **3704** (e.g., a linear track) formed in the body **3701** of the encapsulating attachment **3700**, for example, in a way similar to that described with respect to FIGS. **12**A, **12**B, **12**C, **12**D.

FIG. **37**A depicts that the optics module **3702** is in the first position such that the optics module **3702** is in the field of view of the camera assembly **36** and the field of illumination of the white light source **84** of the mobile device **18**. FIG. **37**B depicts that the optics module **3702** is in the second position such that the field of view of the camera assembly **36** of the mobile device **18** and the field of illumination of the white light source **84** of the mobile device **18** are unobstructed.

In one embodiment, the direction of the track **3704** and the direction in which the optics module **3702** slides in the track **3704** may be generally parallel to the top edge **78** of the mobile device **18**, i.e., the optics module **3702** may slide generally parallel to the top edge **78** from the first position close to the right edge **80** to the second position close to the left edge **82**, or vice versa. In another embodiment, the first position and the second position of the optics module **3702** may be displaced from each other in the direction parallel to the right edge **80** and the left edge **82** of the mobile device **18**, such that the optics module **3702** may slide between the first position adjacent to the top edge **78** of the mobile device and a second position spaced farther away from the top edge **78** of the mobile device **18**, or vice versa. In this embodiment, the track **3704** is generally parallel to the right edge **80** and the left edge **82** of the mobile device **18**. This configuration may be useful when the camera assembly **36** and the white light source **84** of the mobile device **18** are positioned near the center of the back surface **74** (e.g. approximately centered between the right edge **80** and the left edge **82** of the mobile device **18**).

The encapsulating attachment **3700** may include systems including attachment control circuitry **270**, a trigger circuit **161**, a battery **272**, **163**, a user control **288** to initiate the capture of a barcode, a trigger switch **157**, links **276***a*, **276***b*, and/or a microphone connector **155** as discussed with respect to Figures and **14** for interfacing with the mobile device **18** (e.g., via the speaker/microphone connector **34** and/or the power/data connector **64** of the mobile device **18**) and its operating system and any barcode reading application operated thereon. In one embodiment, the systems (including the attachment control circuitry **270**, the trigger circuit **161**, the battery **272**, **163**, the user control **288**, the trigger switch **157**, the links **276***a*, **276***b*, and/or the microphone connector **155**) may be included in a separate detachable package **3703** that may be attached to the encapsulating attachment **3700**. Alternatively, the encapsulating attachment **3700** including such systems may be a single piece.

FIG. **37**C, like FIG. **37**A, depicts the optics module **3702** in the first position. The encapsulating attachment **3700** may include a locking component to lock the optics module **3702** in the first position. For example, the locking component may be a spacer component **3706** which clips into or otherwise engages with the track **3704** and fills the space between the optics module **3702** (when in the first position) and a side edge of the encapsulating attachment **3700** thereby preventing movement of the optics module **3702** when the spacer component **3706** is clipped into the track **3704**. Use of the spacer component **3706** also makes the appearance of the encapsulating attachment **3700** more aesthetically pleasing when the optics module **3702** is in the first position.

FIG. **38** shows an alternative encapsulating attachment **3710** without the separate detachable package **3703**. Whereas the encapsulating attachment **3700** shown in FIGS. **37**A-**37**C may include systems such as attachment control circuitry **270**, a trigger circuit **161**, a battery **272**, **163**, a user control **288** to initiate the capture of a barcode, a trigger switch **157**, links **276***a*, **276***b*, and/or a microphone connector **155**, the encapsulating attachment **3710** shown in FIG. **38** may not include these systems. FIG. **38** depicts the optics module **3702** removed entirely from the track **3704**.

FIGS. **39**A and **39**B are an assembled view and an exploded view of the optics module **3702**, respectively. FIGS. **40**A and **40**B are cross-sectional views of the optics module **3702** along the A-A' and B-B' sections (shown in FIG. **39**A), respectively.

Referring to FIGS. **39**A, **39**B, **40**A, and **40**B, the optics module **3702** is explained in detail. The optics module **3702** includes a chassis **3750**. The chassis **3750** includes a sliding structure (not shown) for engaging with the track **3704** and permitting sliding in the direction of the track **3704** but preventing the optics module **3702** from being removed from the track **3704** (i.e., the sliding structure restricts movement in any direction other than the direction of the track **3704**). The chassis **3750** includes a cavity **3751** in which a mirror support **3764**, a mirror **3766** (i.e., a reflective surface), a collimating lens **3768**, and/or a filter **3762** are accommodated. The mirror support **3764** holds the mirror **3766** within the field of view of the camera assembly **36** and the field of illumination of the white light source **84** of the mobile device **18**. In an embodiment, the mirror support **3764** may hold the mirror **3766** at a 45 degree angle with respect to the optical axis of the camera assembly **36** of the mobile device **18**. The chassis **3750** may include an aperture **3756**, **3757** which may extend around the periphery of the field of view of the camera assembly **36** and the field of illumination of the white light source **84**, respectively. Through the aperture **3756**, **3757** the field of view of the camera assembly **36** and the field of illumination of the white light source **84** may extend into the optics module **3702** when the optics module **3702** is in the active position.

To prevent dirt and debris from accumulating on the mirror **3766** and other components, the interior (e.g., the cavity **3751**) of the optics module **3702** may be sealed with a clear top window **3760** and a clear front window **3770**. In other words, the optics module **3702** may comprise a sealed enclosure. The top window **3760** may sit within a top recess **3758** of the chassis **3750**. The front window **3770** may sit within a front recess **3772** of the chassis **3750**.

The top window **3760** to the sealed enclosure may be generally parallel to the back surface **74** of the mobile device **18**. Through the top window **3760**, the illumination from the white light source **84** enters the sealed enclosure (e.g., via the cavity **3751**) and the illumination from the target area (e.g., the light reflected from the target area including a barcode presented in the target area) exits the sealed enclosure and is incident on the camera assembly **36**. The front window **3770** to the sealed enclosure may be generally perpendicular to the back surface **74** of the mobile device **18**. Through the front window **3770**, the illumination from the white light source **84** exits the sealed enclosure to the target area and the illumination from the target area enters the sealed enclosure and is incident on the mirror **3766**.

The top window **3760** may comprise a first window portion **3760***a* and a second window portion **3760***b*. The first window portion **3760***a* may lie in the field of view of the camera assembly **36** and the second window portion **3760***b* may lie in the field of illumination of the white light source **84** of the mobile device **18**. To prevent illumination from the white light source **84** of the mobile device **18** from affecting the image captured by the camera assembly **36**, a baffle component **3760***c* (e.g., an optical barrier) may separate the first window portion **3760***a* and the second window portion **3760***b*. Because of the baffle component **3760***c*, the illumination from the white light source **84** projected through the second window portion **3760***b* does not, by total internal reflection, propagate to the first window portion **3760***a* and affect the image captured by the camera assembly **36**.

The front window **3770** may comprise a first window portion **3770***a* and a second window portion **3770***b*. The first window portion **3770***a* may lie in the field of view of the camera assembly **36** and the second window portion **3770***b* may lie in the field of illumination of the white light source **84** of the mobile device **18**. To prevent illumination from the white light source **84** of the mobile device **18** from affecting the image captured by the camera assembly **36**, a baffle component **3770***c* (e.g., an optical barrier) may separate the first window portion **3770***a* and the second window portion **3770***b*. Because of the baffle component **3770***c*, the illumination from the white light source **84** projected through the second window portion **3770***b* does not, by total internal reflection, propagate to the first window portion **3770***a* and affect the image captured by the camera assembly **36**.

Alternatively, the top window **3760** and the front window **3770** may comprise two separate windows, respectively. The cavity **3751** may also be separated with a barrier or a wall.

The optics module **3702** may include a collimating optic within the field of illumination of the white light source **84**. The collimating optic is for forming the illumination from the white light source **84** to project a targeting illumination pattern to the target area when the optics module **3702** is in an active position. The collimating optic may comprise a collimating lens **3768** and an aperture **3754**.

For purposes of using the white light source **84** of the mobile device **18** to generate a targeting illumination pattern, the chassis **3750** may include a rectangular-shaped aperture **3754** that restricts the field of illumination of the white light source **84** of the mobile device **18** to a shape that is generally rectangular and within the center of the field of illumination. The restricted rectangular field of illumination may be incident on the mirror **3766** and folded towards the target area. A collimating lens **3768** collimates the rectangular field of illumination to a sharp rectangle that is visible on a surface positioned within the target area.

The collimating optic may further include a filter **3762** for passing a limited spectrum of the illumination emitted by the white light source **84** whereby the targeting illumination pattern, when incident on a surface, appears a color of the limited spectrum. The filter **3762** may be a low pass filter, a band pass filter, a high pass filter, or any type of filter. The filter **3762** (e.g., a blue-colored narrow band filter) may be positioned within the field of illumination of the white light source **84** of the mobile device **18** (e.g., on the top of the chassis **3750** under the top window **3760**) such that the targeting illumination visible within the target area may be primarily the color passed by the filter **3762** (e.g., the blue-colored illumination).

The collimating lens **3768** may be positioned on the front of the mirror **3766** behind the front window **3770**. Alternatively, the collimating lens **3768** may be positioned between the top window **3760** and the mirror **3766**. Alternatively, the collimating lens **3768** may be positioned between the mirror **3766** and the front window **3770**.

As discussed, it is useful to be able to capture an image and decode the barcode while the targeting illumination remains on. However, the targeting illumination may be primarily a single color, and may be much brighter than areas adjacent to the rectangular field of targeting illumination. In addition, the size and shape of the rectangular field of targeting illumination may not be sufficient to illuminate an entire barcode. Image processing may be used to minimize those effects.

FIG. **34** depicts an exemplary image processing method for capturing a barcode while targeting illumination is on. The processing for capturing, decoding, and processing a barcode may be implemented by a barcode reading application running on the mobile device **18**. Step **3410** represents capturing an image by the camera assembly **36** of the mobile device **18** while the targeting illumination is on, outputting the image (e.g., in an RGB format) as described with respect to FIG. **2**E, and saving each of the blue, green, and red channel images (referred to as first, second, and third channel images hereafter). The image capture function of the barcode reading application may control the white light source **84** and the camera assembly **36** of the mobile device **18** to capture a color image of the target area illuminated by illumination generated by the white light source **84** and filtered by the filter **3762**.

The camera assembly **36** of the mobile device **18** may include a color image capture system including an image sensor array for generating a color image of the target area. The white light source **84** of the mobile device **18** generates illumination (e.g., white light) encompassing a first band of illumination, a second band of illumination, and a third band of illumination (e.g., the visible spectrum encompassing the blue, green, and red spectrums of illumination). The illumination from the white light source **84** may be filtered by the filter **3762** to generate targeting illumination of a particular frequency band (e.g., a particular frequency spectrum). For example, the filter **3762** for generating the targeting illumination may be a narrow band filter to generate single-color illumination (e.g., blue illumination). The color image captured by the camera assembly **36** of the mobile device **18** may comprise a first sub-image captured with a portion of the image sensor array sensitive to the first band of illumination, a second sub-image captured with a portion of the image sensor array sensitive to the second band of illumination, and a third sub-image captured with a portion of the image sensor array sensitive to the third band of illumination. Each of the first, second, and third bands may be a red, green, or blue band.

Referring to FIG. **35**A, the color image (shown in grayscale) is a composite image of each of the first, second, and third channel images. The reflection of the rectangular targeting bar **3510** (e.g., the targeting illumination) is clearly shown in FIG. **35**A with the brightness and contrast on the regions of the barcode under the targeting bar **3510** being brighter and higher contrast than the regions of the barcode that are not within the targeting bar **3510**.

In the example shown in FIGS. **35**A-**35**D, the targeting illumination is generated in blue color. However, it should be noted that the embodiments disclosed herein are applicable to targeting illumination of any color. FIG. **35**B depicts the first channel image (the blue channel image). In this example, because the blue channel is most sensitive to the targeting illumination when the targeting illumination is filtered by a band-pass filter passing mostly blue illumination, the targeting bar **3510** within the first channel image is extremely bright and saturated, exceeding the dynamic range of the A/D converters used for digitizing the image.

FIG. **35**C and FIG. **35**D depict the second channel image (the green channel image) and the third channel image (the red channel image), respectively. The green channel image is more sensitive to the blue illumination because it is closer within the visible light spectrum to blue than is the red channel image. The image processing function of the barcode reading application may create a grayscale composite image of the barcode within the target area by combining the first sub-image, the second sub-image, and/or the third sub-image.

Returning to FIG. **34**, step **3412** represents locating the targeting bar **3510** within the image. This step may be performed by identifying the region of saturation in the channel known to be most sensitive to the color of the targeting illumination (e.g., the blue channel if the targeting bar **3510** is produced by a blue-pass filter and appears blue, the red channel if the targeting bar **3510** is produced by a red-pass filter and appears red, and the green channel if the targeting bar **3510** is produced by a green-pass filter and appears green).

Step **3414** represents determining intensity profile values for the remaining channels (e.g., the second and third channels) that are least sensitive to the band of the targeting illumination. The intensity profile value for the first channel may also be determined. The intensity profile values for each channel may be determined based on at least one of: i) brightness and contrast within the region of the image illuminated by the targeting bar **3510** of each sub-image; or ii) brightness and contrast within the regions of the image which are not illuminated by the targeting bar **3510** of each sub-image.

Step **3416** represents determining ratios (or weights) for combining each of the first, second, and third channels to generate a grayscale composite image for further image processing and decoding. In more detail, the intensity profile values of the second and third channels (or alternatively all three channels) may be input to a function which generates a ratio (or weights) for combining the first, second, and third channels. The function may be a look-up table which maps combinations of ranges of each of the intensity profile values to combinations of ratios or weights.

For example, eight values including i) the brightness and contrast within the region of the image illuminated by the targeting bar **3510** for each of the second and third channels, and ii) the brightness and contrast within the regions of the image which are not illuminated by the targeting bar **3510** for each of the second and third channels may be input to a multi-dimensional look-up table to generate percentage values (e.g., weights or ratios) for the first, second, and third channel images. Different sets of input values may be used to determine the combining ratios or weights.

In determining the ratios or weights for generating the composite image, a contribution (e.g., the ratio or weight) from a sub-image captured by a portion of the image sensor array most sensitive to the frequency spectrum of the targeting illumination may be smaller than a contribution from the other two sub-images captured by the other two portions of the image sensor array.

Alternatively, the contribution from a sub-image captured by a portion of the image sensor array most sensitive to the frequency spectrum of the targeting illumination may be zero. For example, consider a case where the first band, the second band, and the third band of illumination are a red band, a green band, and a blue band, respectively, and the first sub-image, the second sub-image, and the third sub-image are images captured by the portion of the image sensor being most sensitive to red, green, and blue illumination, respectively. If the band of targeting illumination passed by the optical filter **3762** is a green band of illumination, the grayscale composite image may be a combination of the first and third sub-images. If the band of targeting illumination passed by the optical filter **3762** is a red band of illumination, the grayscale composite image may be a combination of the second and third sub-images. If the band of targeting illumination passed by the optical filter **3762** is a blue band of illumination, the grayscale composite image may be a combination of the first and second sub-images.

Step **3418** represents creating a combined image. For each pixel of the grayscale image, the digital gray level value of the composite image is the result of summing: i) the pixel value of the first channel image multiplied by the first channel ratio (or weight); ii) the pixel value of the second channel image multiplied by the second channel ratio (or weight); and iii) the pixel value of the third channel image multiplied by the third channel ratio (or weight).

As an example, depicted in FIG. **36**A is a grayscale image resulting from summing, for each pixel of the image: i) the pixel value of the first channel image (blue) multiplied by the first channel ratio (0%); ii) the pixel value of the second channel image (green) multiplied by the second channel ratio (30%); and iii) the pixel value of the third channel image (red) multiplied by the third channel ratio (70%).

As another example, depicted in FIG. **36**B is a grayscale image resulting from summing, for each pixel of the image: i) the pixel value of the first channel image (blue) multiplied by the first channel ratio (0%); ii) the pixel value of the second channel image (green) multiplied by the second channel ratio (15%); and iii) the pixel value of the third channel image (red) multiplied by the third channel ratio (85%).

A decoder function of the barcode reading application may receive the grayscale composite image of the barcode and generate decoded data representing data encoded in the barcode. A relay function of the barcode reading application may then send the decoded data to a (remote) server, for example, via a wireless connection established between the mobile device **18** and a network.

As discussed previously, a barcode-reading system in accordance with the present disclosure may include a barcode-reading enhancement accessory that is securable to a mobile device. The accessory may improve the barcode-reading capabilities of the mobile device. In accordance with another aspect of the present disclosure, targeting illumination projected by the accessory may be used to estimate the distance between the mobile device and a barcode, and this information may be used to adjust one or more operating parameters of the mobile device. This process may be referred to herein as ranging.

In the discussion that follows, reference will be made to the mobile device **18** shown in FIG. **2**A (and subsequent figures). As discussed previously, the mobile device **18** may include a camera assembly **36**, a white light source **84** for providing illumination, a processor **44**, and memory **46**. A barcode-reading application **24** may be stored in the memory **46** and executed by the processor **44**.

Reference will also be made to the accessory **3700** shown in FIG. **37**A (and subsequent figures). As discussed previously, the accessory **3700** may include an optic system that is positionable within the field of illumination of the white light source **84** of the mobile device **18** when the accessory **3700** is secured to the mobile device **18**. The optic system may be configured to shape and filter the illumination from the white light source **84** to project targeting illumination onto a surface that is located within the field of view of the camera assembly **36**.

More specifically, as discussed above, the optic system may include an aperture **3754**, a collimating lens **3768**, and a filter **3762**. The aperture **3754** may be configured to restrict the field of illumination of the white light source **84** of the mobile device **18** to a particular shape, such as a rectangular shape. The collimating lens **3768** may be configured to collimate the rectangular field of illumination to a rectangular targeting bar **3510**. The filter **3762** may be configured to pass a limited spectrum of the illumination emitted by the white light source **84**, so that the targeting bar **3510**, when incident on a surface, appears as the color of the limited spectrum. Thus, the targeting illumination may be primarily a single color (e.g., green). The application **24** may be configured to utilize known image processing techniques to identify the targeting illumination within an image (e.g., an image of a barcode).

The offset (or distance) between certain features of the targeting illumination may vary with the distance between the mobile device **18** and a surface on which the targeting illumination is projected. The surface on which the targeting illumination is projected may be referred to herein as the "target surface." The distance between the mobile device **18** and the target surface may be referred to herein as the "surface distance."

FIGS. **41**A-C illustrate images **4108***a-c* of targeting illumination projected by an accessory **3700** onto a target surface **4104** at three different surface distances. More specifically, FIG. **41**A illustrates an image **4108***a* of the targeting illumination projected on the target surface **4104** at a surface distance D_1, FIG. **41**B illustrates an image **4108***b* of the targeting illumination projected on the target surface **4104** at a surface distance D_2, and FIG. **41**C illustrates an image **4108***c* of the targeting illumination projected on the target surface **4104** at a surface distance D_3, where $D_1<D_2<D_3$. In other words, the mobile device **18** is positioned closest to the target surface **4104** in FIG. **41**A, farther away from the target surface **4104** in FIG. **41**B, and farthest away from the target surface **4104** in FIG. **41**C. A barcode **4102** is printed or otherwise displayed on the target surface **4104**.

In the depicted embodiment, the targeting illumination includes a rectangular targeting bar **4110**. The width of the targeting bar **4110** may be defined as the distance between the left edge **4114** and the right edge **4116** of the targeting bar **4110**. As can be seen in the images **4108***a-c* shown in FIGS. **41**A-C, as the surface distance increases (i.e., as the distance between the mobile device **18** and the target surface

4104 increases), the width of the targeting bar 4110 increases. More specifically, when the mobile device 18 is positioned relatively close to the target surface 4104 (as in the image 4108*a* shown in FIG. 41A), only limited divergence occurs between the left edge 4114 and the right edge 4116 of the targeting bar 4110, such that the targeting bar 4110 is relatively narrow. However, as the mobile device 18 is moved farther away from the target surface 4104 (as in the images 4108*b-c* shown in FIGS. 41B and 41C), the amount of divergence between the left edge 4114 and the right edge 4116 of the targeting bar 4110 increases, such that the targeting bar 4110 becomes increasingly wider. Thus, the targeting bar 4110 is narrowest in the image 4108*a* shown in FIG. 41A, somewhat wider in the image 4108*b* shown in FIG. 41B, and widest in the image 4108*c* shown in FIG. 41C. The barcode 4102 appears increasingly smaller in the images 4108*a-c* (largest in the image 4108*a* shown in FIG. 41A, somewhat smaller in the image 4108*b* shown in FIG. 41B, and smallest in the image 4108*c* shown in FIG. 41C) because of the increasing distance between the mobile device 18 and the target surface 4104.

As used herein, the term "feature offset" may refer to an offset (or distance) between distinct features of the targeting illumination. The width of the targeting bar 4110 shown in FIGS. 41A-C is an example of a feature offset. In this example, there is a single shape (the targeting bar 4110), and the width of the targeting bar 4110 represents the offset between different parts of that shape (the left edge 4114 and the right edge 4116 of the targeting bar 4110). Alternatively, the targeting illumination may include separate shapes, and the offset between the separate shapes may be determined and used to determine surface distance.

Features of targeting illumination may be offset from one another in the horizontal direction only, the vertical direction only, or in both the horizontal and vertical directions. Thus, a feature offset may include a horizontal component only, a vertical component only, or both a horizontal component and a vertical component.

In the example shown in FIGS. 41A-C, the offset between features of the targeting illumination is proportional to surface distance (i.e., the offset increases as surface distance increases). Alternatively, however, the offset between features of the targeting illumination may be inversely proportional to surface distance (i.e., the offset may decrease as surface distance increases).

Although FIGS. 41A-C depict the targeting illumination as a targeting bar 4110, the targeting illumination may take other forms in accordance with the present disclosure. A targeting illumination system in accordance with the present disclosure may project a single shape or multiple shapes. For example, the targeting illumination may include non-parallel targeting beams 138*a-b* as shown in FIG. 7B, any of the targeting patterns described with respect to FIGS. 8A-D, etc. Features projected by a targeting illumination system may have any of a wide variety of shapes, including solid shapes, hollow shapes, and combinations thereof. Further, such shapes may include curvilinear shapes, rectilinear shapes, and combinations thereof. Some examples are circles, crosses, triangles, rectangles, parallelograms, other polygons, ellipses, annular shapes, and the like.

The mobile device 18 may store calibration data that indicates a relationship between surface distance and at least one feature offset of the targeting illumination. FIG. 42 illustrates calibration data in accordance with an embodiment. In the depicted embodiment, the calibration data is stored in a lookup table 4218. The lookup table 4218 may include a plurality of surface distance fields (D_1, D_2, D_3, . . .) and a plurality of feature offset fields (O_1, O_2, O_3, . . .). More specifically, the lookup table 4218 may include a plurality of records, and each record may include a feature offset field (O_i) that is associated with (or linked to) a particular surface distance field (D_i). For example, the lookup table 4218 may include a first record that includes feature offset field O_1 associated with surface distance field D_1, a second record that includes feature offset field O_2 associated with surface distance field D_2, etc. Thus, each feature offset field (O_i) may be associated with (or linked to) a corresponding surface distance field (D_i).

The feature offset field (O_i) in a particular record may indicate the feature offset of the targeting illumination (e.g., the width of the targeting bar 4110) in an image that is captured by the camera assembly 36 of the mobile device 18 when the surface distance (i.e., the distance between the mobile device 18 and the target surface 4104) is equal to the value of the corresponding surface distance field (D_i).

FIG. 43 illustrates calibration data in accordance with another embodiment. In this embodiment, the calibration data is again stored in a lookup table 4318. However, this lookup table 4318 includes more information than the lookup table 4218 shown in FIG. 42. More specifically, each record in the lookup table 4318 is shown with the following fields: a surface distance field (D_i), a first location field $(x_1, y_1)_i$, a second location field $(x_2, y_2)_i$, and a feature offset field (O_i).

The surface distance field (D_i) may indicate a surface distance. The first location field $(x_1, y_1)_i$ may indicate a location of a first feature of the targeting illumination (e.g., the left edge 4114 of the targeting bar 4110) in an image taken at the surface distance. This image may be referred to herein as a calibration image, for reasons that will be explained below. The second location field $(x_2, y_2)_i$ may indicate a location of a second feature of the targeting illumination (e.g., the right edge 4116 of the targeting bar 4110) in the calibration image. The feature offset field (O_i) may indicate the feature offset of the targeting illumination in the calibration image. More specifically, the feature offset field (O_i) may indicate a difference between the location of the first feature of the targeting illumination in the calibration image and the location of the second feature of the targeting illumination in the calibration image.

Other configurations of the calibration data are possible in accordance with the present disclosure. For example, each record in the lookup table 4318 may include the surface distance field (D_i), the first location field $(x_1, y_1)_i$, and the second location field $(x_2, y_2)_i$, and the feature offset field (O_i) may be calculated when necessary.

It is also not necessary that the calibration data take the form of a lookup table. The calibration data may be any tool that can be used to determine the distance of a surface from the mobile device 18 based on the offset of features in targeting illumination. For example, in some embodiments, the calibration data may simply take the form of a mathematical formula. A mathematical formula may be utilized, for example, when the offset between features of the targeting illumination varies linearly with surface distance. The mathematical formula may receive a feature offset of the targeting illumination as input, and provide an estimated surface distance as output.

FIG. 44 illustrates a method 4400 for determining calibration data. The method 4400 may be performed as part of a calibration process for the accessory 3700 and/or for the mobile device 18. Under some circumstances, such a calibration process may be performed on a single occasion (e.g., during manufacturing or after initial purchase). Under other circumstances, however, calibration may be performed periodically.

In step **4402** of the method **4400**, the mobile device **18** may be positioned at a known surface distance. More specifically, the mobile device **18** may be positioned so that the distance between the mobile device **18** and a target surface **4104** (which, for purposes of this method **4400**, may or may not include a barcode **4102**) is known.

In step **4404**, the application **24** may cause the accessory **3700** to project targeting illumination (e.g., a rectangular targeting bar **4110**) onto the target surface **4104**.

In step **4406**, the application **24** may cause the camera assembly **36** of the mobile device **18** to capture an image of the target surface **4104**. The image may be captured while the mobile device **18** is positioned at the known distance from the target surface **4104**, and while the targeting illumination is being projected onto the target surface **4104**. Thus, the image that is captured may include the targeting illumination. The image may be referred to herein as a calibration image, because it is captured for the purpose of determining calibration data.

In step **4408**, the application **24** may determine information about the calibration image that was captured in step **4406**. For example, if the calibration data takes the form of the lookup table **4318** shown in FIG. **43**, the application **24** may determine the location of a first feature of the targeting illumination (e.g., the left edge **4114** of the targeting bar **4110**) in the calibration image and the location of a second feature of the targeting illumination (e.g., the right edge **4116** of the targeting bar **4110**) in the calibration image. Various image processing algorithms may be used to determine the locations of these features. The application **24** may also determine the offset between the location of the first feature and the location of the second feature (e.g., the width of the targeting bar **4110**) in the calibration image. The locations that are determined, and the offset between those locations, may include only an x coordinate, only a y coordinate, or both x and y coordinates.

In step **4410**, the application **24** may record the information that was determined in step **4408** in the calibration data. For example, if the calibration data takes the form of a lookup table, this may involve creating a new record for the lookup table and recording the information that was determined in step **4408** in the appropriate fields of the lookup table.

In step **4412**, the application **24** may determine whether a sufficient amount of calibration data has been determined. This may involve determining whether calibration data has been determined for all of the surface distances of interest. If the application **24** determines that a sufficient amount of calibration data has been determined, the method **4400** may end. If the application **24** determines that a sufficient amount of calibration data has not been determined, the method **4400** may proceed to step **4414**, in which the mobile device **18** may be positioned at a different surface distance (i.e., a surface distance for which calibration data has not previously been determined). The method **4400** may then return to step **4404** and proceed as described above.

Steps **4404** through **4414** may be performed multiple times, so that a plurality of calibration images are captured by the camera assembly **36** and information about the plurality of calibration images is recorded in the calibration data. Generally speaking, increasing the amount of calibration data that is collected improves the accuracy of surface distance estimation.

Calibration data may be determined in other ways as well. For example, a plurality of feature offsets may be calculated based on known divergence of the targeting illumination. These feature offsets may be stored as calibration data (e.g., in a lookup table) instead of or in addition to the feature offsets calculated in the method **4400** of FIG. **44**.

FIG. **45** illustrates a method **4500** for obtaining ranging data in accordance with an embodiment. More specifically, the method **4500** may be implemented in order to estimate the distance between the mobile device **18** and a target surface **4104**, which may include a barcode **4102** printed or otherwise displayed thereon. The method **4500** may be performed while the mobile device **18** is being used to read one or more barcodes **4102**.

In step **4502**, the application **24** may cause the accessory **3700** to project targeting illumination onto a target surface **4104**. A barcode may be printed or otherwise displayed on the target surface **4104**.

In step **4504**, the application **24** may cause the camera assembly **36** of the mobile device **18** to capture an image of the target surface **4104**. The image may include the barcode on the target surface **4104**, as well as the targeting illumination projected onto the target surface **4104**.

In step **4506**, the application **24** may determine a feature offset of the targeting illumination in the image that was captured in step **4504**. For example, in an embodiment where the targeting illumination includes a rectangular targeting bar **4110** (as shown in FIGS. **41**A-C), determining the feature offset may include determining the width of the rectangular targeting bar **4110**.

As discussed above, the optic system in the accessory **3700** may include an optical filter **3762** that is configured to pass a limited spectrum of the illumination emitted by the white light source **84**. As also discussed above, an image captured by the camera assembly **36** of the mobile device **18** may include a plurality of channel images (e.g., red, green, and blue channel images). In accordance with an embodiment, the application **24** may be configured so that it only uses one channel image of the plurality of channel images to determine the feature offset of the targeting illumination. The channel image that is used may be the one that is most sensitive to the limited spectrum that is passed by the optical filter **3762**. More specifically, the channel image that is used may be more sensitive to the limited spectrum that is passed by the optical filter **3762** than other channel images of the plurality of channel images.

In accordance with one or more embodiments, the optical filter **3762** may be configured to pass a specific color of illumination, so that the targeting bar **4110** appears to be a specific color (e.g., green). In such embodiments, the application **24** may be configured to use the corresponding channel image (e.g., the green channel image) to determine the feature offset of the targeting illumination. For example, in embodiments where the targeting bar **4110** appears green, the targeting bar **4110** may be more easily detected in the green channel image than in the red channel image or the blue channel image.

In embodiments where the optical filter **3762** is configured to pass green illumination, the optical filter **3762** may be configured to pass light having a wavelength of about 510 nm, and filter other wavelengths of light. In one embodiment, a wavelength of about 510 nm refers to any wavelength in the range of 500-520 nm. In another embodiment, a wavelength of about 510 nm refers to any wavelength in the range of 490-530 nm.

Returning to the method **4500** shown in FIG. **45**, in step **4508**, the application **24** may determine an estimated surface distance based on the calibration data and the feature offset that was determined in step **4506**. In an embodiment where the calibration data takes the form of a lookup table (as shown in FIGS. **42** and **43**, for example), determining the estimated surface distance may include identifying the feature offset field (O_i) whose value is closest to the feature offset that was determined in step **4506**, and returning the value of the corresponding surface distance field (D_i) as the estimated surface distance. For example, referring to the lookup table **4218** shown in FIG. **42**, if the value of the feature offset field O_2 is closer to the feature offset that was determined in step **4506** than the value of any of the other feature offset fields in the lookup table **4218**, then the value of the corresponding surface distance field D_2 may be returned as the estimated surface distance.

Alternatively, determining the estimated surface distance may include interpolating the estimated surface distance using the calibration data and the feature offset that was determined in step **4506**. For example, referring again to the lookup table **4218** shown in FIG. **42**, suppose that the feature offset that was determined in step **4506** is between the value of the feature offset fields O_2 and O_3. In this case, interpolation between those values may be performed to provide an estimated surface distance that is between the values of the corresponding surface distance fields D_2 and D_3.

In an embodiment where the calibration data takes the form of a mathematical formula, determining the estimated surface distance may include providing the feature offset that was determined in step **4506** as input to the formula. The formula may then return the estimated surface distance as output.

In step **4510**, the application **24** may use the estimated surface distance that was determined in step **4508** to adjust at least one operating parameter of the mobile device **18**. The adjustment may optimize image capture at the estimated surface distance. For example, the application **24** may adjust the intensity of the illumination provided by the white light source **84** of the mobile device **18**. The intensity may be varied in proportion to the estimated surface distance. More specifically, the intensity may be increased as the estimated surface distance increases (i.e., as the mobile device **18** is moved farther away from the barcode **4102**), and vice versa.

One or more of the features, functions, procedures, operations, components, elements, structures, etc. described in connection with any one of the configurations described herein may be combined with one or more of the functions, procedures, operations, components, elements, structures, etc. described in connection with any of the other configurations described herein, where compatible.

The steps and/or actions of the methods described herein may be interchanged with one another without departing from the scope of the claims. In other words, unless a specific order of steps or actions is required for proper operation of the method that is being described, the order and/or use of specific steps and/or actions may be modified without departing from the scope of the claims.

The claims are not limited to the specific implementations described above. Various modifications, changes and variations may be made in the arrangement, operation and details of the implementations described herein without departing from the scope of the claims.

What is claimed is:

1. A barcode-reading system for a computing device, the computing device comprising a camera assembly and a white light source for illuminating a target, the barcode-reading system comprising:

a barcode-reading enhancement accessory securable to the computing device, the barcode-reading enhancement accessory comprising an optic system that is positionable within a field of illumination of the white light source when the barcode-reading enhancement accessory is secured to the computing device, the optic system being configured to shape a targeting illumination projected by the white light source; and

a barcode-reading application stored in memory of the computing device, the barcode-reading application being executable by a processor of the computing device to:

determine a feature offset of the targeting illumination in an image that is captured by the camera assembly of the computing device; and

based on the determined feature offset, adjust one or more operating parameters of the computing device.

2. The barcode-reading system of claim **1**, wherein the computing device comprises a mobile device.

3. The barcode-reading system of claim **1**, wherein the barcode-reading application is executable by the processor of the computing device to maintain calibration data, the calibration data comprising one or more relationships between feature offsets of targeting illuminations and surface distances associated with corresponding operating parameters.

4. The barcode-reading system of claim **3**, wherein determining the estimated surface distance comprises:

identifying the feature offset from the calibration data; and

identifying the one or more operating parameters based on a relationship between the feature offset and a surface distance from the calibration data associated with at least one operating parameter.

5. The barcode-reading system of claim **3**, wherein the calibration data comprises a plurality of records, wherein at least one record from the plurality of records comprises:

a surface distance field that indicates a first surface distance;

a first location field that indicates a location of a first feature of the targeting illumination in a calibration image taken at the first surface distance;

a second location field that indicates a location of a second feature of the targeting illumination in the calibration image; and

a feature offset field indicating a difference between the location of the first feature of the targeting illumination in the calibration image and the location of the second feature of the targeting illumination in the calibration image.

6. The barcode-reading system of claim **3**, wherein the calibration data comprises a feature offset prediction model comprising a mathematical formula that:

receives, as an input, the feature offset of the targeting illumination; and

provides, as an output, the estimated surface distance.

7. The barcode-reading system of claim **1**, wherein adjusting the one or more operating parameters of the computing device comprises adjusting intensity of an illumination provided by the white light source of the computing device.

8. The barcode-reading system of claim **1**, wherein the optic system comprises an aperture configured to shape the targeting illumination projected by the white light source by restricting the field of illumination of the white light source to a shape.

9. The barcode-reading system of claim **8**, wherein determining the feature offset of the targeting illumination comprises determining a horizontal or vertical dimension of the shape.

10. The barcode-reading system of claim **8**, wherein determining the feature offset of the targeting illumination comprises determining a dimension of the shape that varies based on a surface distance, the surface distance comprising a distance between the computing device and a surface on which the targeting illumination is projected.

11. The barcode-reading system of claim **8**, wherein the aperture is configured to restrict the field of illumination of the white light source to one or more of:

a rectangular shape, wherein the feature offset comprises a width or height of the rectangular shape; or

a targeting line, wherein the feature offset comprises a width of the targeting line.

12. The barcode-reading system of claim **1**, wherein:

the optic system is further configured to filter the targeting illumination by passing a limited spectrum of the white light source; and

determining the feature offset of the targeting illumination comprises detecting the feature offset of a portion of the image having a wavelength corresponding to the limited spectrum of the white light source.

13. A barcode-reading application for a computing device that comprises at least one processor, memory, a camera assembly, and a white light source for emitting illumination, the barcode-reading application comprising executable code that, when stored in the memory and executed by the at least one processor, causes the computing device to:

determine a feature offset comprising a dimension of a shape of a targeting illumination in an image that is captured by the camera assembly of the computing device, wherein the targeting illumination is produced by an optic system of a barcode-reading enhancement accessory that is secured to the computing device; and

based on the feature offset, adjust at least one operating parameter of the computing device.

14. The barcode-reading application of claim **13**, wherein the computing device comprises a mobile device.

15. The barcode-reading application of claim **13**, wherein the executable code, when executed by the at least one processor, causes the computing device to maintain calibration data, the calibration data comprising one or more relationships between feature offsets of targeting illuminations and surface distances associated with corresponding operating parameters.

16. The barcode-reading application of claim **15**, wherein the executable code, when executed by the at least one processor, causes the computing device to:

identify the feature offset from the calibration data; and

identify the one or more operating parameters based on a relationship between the feature offset and a surface distance from the calibration data associated with at least one operating parameter.

17. The barcode-reading application of claim **15**, wherein the calibration data comprises a plurality of records, wherein at least one record from the plurality of records comprises:

a surface distance field that indicates a first surface distance;

a first location field that indicates a location of a first feature of the targeting illumination in a calibration image taken at the first surface distance;

a second location field that indicates a location of a second feature of the targeting illumination in the calibration image; and

a feature offset field indicating a difference between the location of the first feature of the targeting illumination in the calibration image and the location of the second feature of the targeting illumination in the calibration image.

18. The barcode-reading application of claim **13**, wherein:

the optic system comprises an aperture configured to shape the targeting illumination projected by the white light source by restricting a field of illumination of the white light source to a shape having one or more dimensions that vary based on a surface distance comprising a distance between the computing device and a surface on which the targeting illumination is projected; and

determining the feature offset of the targeting illumination comprises determining a horizontal or vertical dimension of the shape.

19. The barcode-reading application of claim **18**, wherein the aperture is configured to restrict the field of illumination of the white light source to one or more of:

a rectangular shape, wherein the feature offset comprises a width or height of the rectangular shape; or

a targeting line, wherein the feature offset comprises a width of the targeting line.

20. The barcode-reading application of claim **13**, wherein:

the optic system is further configured to filter the targeting illumination by passing a limited spectrum of the white light source; and

determining the feature offset of the targeting illumination comprises detecting the feature offset of a portion of the image having a wavelength corresponding to the limited spectrum of the white light source.

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